Applied Economics Journal 18 Number 1 (June 2011): 31-43

ISSN 0858-9291

An Analysis of Supply Response for Natural Rubber in Cambodia

Samin Much*
Kampong Cham National School of Agriculture, Kampong Cham Province, Cambodia
Sopin Tongpan
Faculty of Economics, Kasetsart Unversity, Bangkok, 10900, Thailand, E-mail: agriecon@hotmail.com
Prapinwadee Sirisupluxana
Faculty of Economics, Kasetsart Unversity, Bangkok, 10900, Thailand, E-mail: fecopds@gmail.com

In this paper, a partial adjustment and adaptive expectation mechanism are applied to analyze the supply response of natural rubber in Cambodia. The planted area and average yield are set as the supply response. Data from 1990-2008 were used in the analysis. The factor that had the most positive influence on the supply was rubber prices followed by rainfall and lagged dependent variables. However, the supply negatively responded to prices of alternative crops. In terms of elasticities of rubber supply with respect to its own price, they were inelastic in the short run and elastic in the long run. The long-run supply elasticities were relatively greater than the short run by five to twenty times. That indicates rubber farmers adjust their production planning in the long run more frequently than in the short run.

Keywords: natural rubber, supply response, Cambodia
JEL Classification: C12, C22, C32, D24, Q11

Introduction

Supply analysis of agricultural products is an important contribution to production planning by farmers. Rubber tree is a perennial crop which supply is related to planted area and average yield per unit area. The cultivators can increase future production by planting/replanting and improving yield. In particular, when the producer price is higher, the growers increase rubber production by either expanding planted area or increasing rubber yield. In contrast, farmers would stop tapping or switch to work in the other farms whenever the rubber price falls. And if the rubber price is lower and the rubber tree is less productive, the farmers cut down the trees and sell them as rubber wood. Furthermore,

* Corresponding author: Samin Much, Kampong Cham National School of Agriculture, Road no. 7, Kampong Cham Province, Kampong Cham Town, Tel: (+855) 1238 1581, E-mail: saminmuch@yahoo.com

rubber yield is related to relative crop prices and weather condition. For example, when the alternative crop prices increase, farmers tend to switch to those crops. This leads to the decline in the planted area of rubber tree.

In this paper, we examine how Cambodian rubber producers adjust their production plan in response to economic and non-economic factors such as rubber price, other competitive/alternative crop prices and weather condition. In order to explain the rubber supply change, we use the data from 1990-2008, after the government adopted the free market economy, and apply ordinary least square (OLS) method to estimate the supply response.

A review of studies of supply response in agricultural commodity for perennial crops shows that most researchers develop several models of the investment in planting and production of tree crops. Up to the early 1990s, the advanced development of models can be traced from many studies. Bateman (1962) developed the investment model for cocoa planting in Ghana by postulating that cocoa price and competitive coffee price expectations are the major determinants of the cocoa planting decision. In his model, Nerlove adaptive price expectation scheme is used to transform the expected price into determinants of cocoa planting. The actual planted area is related to observed price variables and the output is a function of actual planting, observed price variables and environmental factors. The results show that the producer price had little impact on harvesting decision.

Chan (1962) examined the production of rubber output of Malaysia. In his view, planted area depends upon price expectation of several years before tapping begins. Chan used a simple non-Nerlovian supply model in which rubber output is expressed as a function of current price to examine the short-run harvesting effect. Behrman and Klein (1970) constructed a multi-model for Brazilian coffee considering planted area and yield. Particularly, the coffee planted area is expressed as a function of two-period lags of domestic coffee price and the planted area of last year. They assumed that average yield of coffee depends on lags of domestic coffee price and rainfall. The results show that the determinant coefficient of planted area was higher than the average coffee yield. Specifically, the rank R^2 values of planted area and average coffee yield were 0.95 and 0.52, respectively.

Wickens and Greenfield (1973) separately developed the models of vintage production, investment and harvesting decision on coffee in Brazil. They constructed the model of the planted area of coffee as a function of recent and past coffee prices. Then, they combined the structural equation into a single production. Furthermore, they used a lagged variable technique to estimate a reduced form model. Based on their study, numerous researchers have applied their approach to analyze the supply response of tree crops. Meanwhile Dowling (1979) derived a reduced form in a slightly different way, but obtained an almost identical estimating equation as W&G's work. He assumed that actual output is determined by potential production and a short, non-adaptive distributed lags of past price. He also used the rice price as an independent variable. Interestingly, the result was more satisfactory than using the natural rubber price alone. Based on these works, we can conclude that these authors use nearly the same factors to explain supply response of perennial trees.

Some authors advocate the structural approach to estimate separated equations of planting, removing and harvesting (French, King, and Minami, 1985; Hartley, Nerlove, and Peter, 1984; 1987). In particular, Hartley *et al.* (1987), due to the lack of data, constructed a supply response for rubber in Sri Lanka in separated structural equations. They found that the actual output may differ from potential output due to weather condition, current price, old stand trees and diseases/damage. This leads to the actual output was a function of potential output, current price, expected price, wage rate and the time trend. Their regression demonstrates that the coefficient of potential output is significant with expected positive sign. Therefore, a significant aspect of rubber supply in Sri Lanka is the steady state of technological improvement resulting in high yielding trees and a different age yield profile.

The farmer's supply response to price incentives along with the other supply shifter variables was advanced by Nerlove (1958). Heady *et al.* (1958) proposed that the variables of factor prices are the main cause of the shift in supply. Supply response can be considered in terms of output production, planted area or average of crop yield. In fact, the production of any agricultural crop is generated by harvested area and average crop yield per unit area.

Based on the literature above, it is crucial to understand the determinants of planted area and yield per hectare a year. In this paper, we aim to provide the knowledge of the supply response of natural rubber in Cambodia. The main concept of supply response is elaborated in the next section followed by the model specification and data collection. Results are then presented and discussed. Conclusion is in the last section.

Conceptual Framework

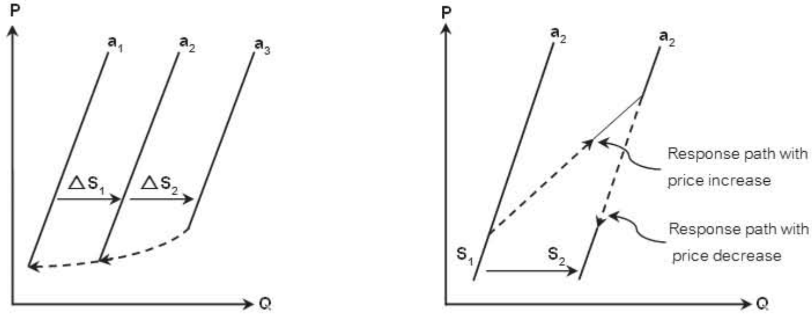
The nature of agricultural product supply is more diverse than agricultural commodity demand. While the agricultural demand is primarily determined by purely economic factors, the theory of supply expresses producers' response to both economic and non-economic factors, including ecological conditions, and technological improvement and policies. Tomek and Robinson (1990) proposed that the market supply curve is defined as the relationship between price and aggregate quantity offered for sale by all producers per time period. Moreover, Nerlove (1958) noted that the supply curve is defined only within the context of a competitive structure where sellers are price takers. Theoretically, Heady *et al.* (1958) defined that the quantity of supply depends on the commodity price, the price of input used such as fertilizer and the price of other commodities that could be produced by using the same resources. By assuming that all other variables remain constant, the producers increase supply when the offered price is higher. It means that when the price increases, the supply curve moves upward to the right and when the price decreases the reverse happens.

Heady *et al.* (1958) also proposed that supply response and supply function relation are two concepts which are often used synonymously. Response relation is not a reversible function in the sense that a supply function is reversible. The response relation is more general, it specifies the changes of the quantity supplied in response to changes in price and the other determinants. The structural change involves change in ceteris paribus condition and the other variables. Such supply shifters is not as common as the supply function. The response concept is based on the hypothesis that when price factor changes, there are likely to be correlated changes in the form of environmental factor relationship. Shift in supply results from changes in the values of the variables other than price and quantity. For instance, when the price increases, a new production technology should be employed or weather condition will affect the crop yield. Therefore, an increase in price can be expected to have two effects: firstly, it will force farmers to increase the output along with the supply curve, and secondly, it will lead them to the new supply curve. Thus, the supply response relation is the shift of supply resulting from the changes in more than one parameters or a change in the form of relationship.

From the viewpoint of supply response models and their endogenous and exogenous components, Askari and Cummings (1976) proposed that crop trees may require special treatments on almost every level of quantitative analysis. The supply of products from perennial trees hinges on their long gestation and productive lifecycle, which features are fundamental to understanding the investment and production behavior in the industry. Thus, the perennial crop growers must consider the longer time horizon. The main effects on supply response of perennial trees take place through the investment, disinvestment and yield mechanism. The main factors that affect the supply of agricultural commodities are price factors.

From the above theoretical discussion and literature review, the supply function and response relation can be depicted by Figure 1a and 1b. In Figure 1a, the change in supply of a commodity consists of two parts: (1) moving up and down a given supply functions a_1, a_2, or a_3, in response to price and (2) the growth or shift of supply (ΔS_1 and ΔS_2). This happens through time accomplished by investment in planting or fixed resources and the adoption of new technologies, which over the relevant range in prices, takes the form of investment in plant. Thus, response of agricultural product is related to a number of variables, among which are the price and environmental factors.

As demonstrated by Figure 1b, this framework further suggests that when the price increases, producers expand production along the diagonal line between supply curve S_1 and S_2, which we call a response path with a price increase. On the other hand, decline in price leads to the reduction of output along with the new supply curve S_2, which is called response path with a subsequent price decrease. Thus, supply response investigates more variables in the form of relationship not only on product price but also the other relevant factors in the supply relation.



(a) Supply relation through time (b) Supply response relation paths

Figure 1 The supply function and supply response relationship

Source: Heady *et al.* (1958) and Tomek and Robinson (1990)

Model Specification

Planting tree crops has to wait for several years until the trees can produce, which can take at least five to six years. Generally, such perennial as rubber trees have, at a certain stage presents a yield profile which indicates potential yield. In particular, it takes several years after planting before any output is obtained. After that, the yield increases to peak at maturity and then gradually declines to level where it is no longer profitable. Consequently, the plantation must be renewed. According to Bateman (1962), the age profile of existing stock trees affects per hectare yield and thus total output in any given period. However, from age-yield profile, rubber cultivators can make a decision on whether or not to replant a stand of rubber tree of a given age.

Rubber tree produces latex five years from planting in the context of Cambodian environmental conditions. The change of rubber planted area resulted from new planting or replanting is assumed to be affected by some economic factors such as its own price and the prices of alternative crops that are grown in the same area. Thus, the decision to plant/replant depends on the past prices of natural rubber and current alternative crop prices. By assuming that the losses due to disease infection, damage and removal are relatively small, and using the change in planted area proxies for new rubber planted area, the relationship of new planted area on natural rubber can be expressed as:

$$\Delta A_t = a_0 + a_1 P_{t-1} + a_2 P_{t-2} + a_3 Z_t + u_t \qquad (1)$$

where $\Delta A_t = A_t - A_{t-1}$ is the new planted area in period *t*, P_{t-1} is rubber price in period *t-1*, P_{t-2} is rubber price in period *t-2*, Z_t is current alternative crop prices and u_t is error term in period *t*.

The Equation (1) states that new planted area of rubber trees is a function of lagged rubber prices and alternative crop prices. Since the new planted area cannot be directly observed, it must be reflected by the other observed variables. Given the partial adjustment model that relates the new planted area to actual planted area in previous period, the new planted area can be expressed as:

$$A_t - A_{t-1} = \mu(\Delta A_t - A_{t-1}) \qquad (2)$$

where A_t is the actual rubber planted area in this year, A_{t-1} is the actual rubber planted area in last year and μ is the coefficient of adjustment.

Equation (2) states that the new planted area is proportional to the difference between the new and actual planted area in the immediate-past by the speed of coefficient of adjustment. It is postulated that, farmers can maximize profits by planting new planted area in a fraction of μ which is the difference between the area they would like to plant and the area actually planted in the preceding year. If μ approaches zero, there is no newly planted area. On the other hand, if $\mu = 1$, adjustment is instantaneous. By rearranging Equation (2) and substituting into (1), we obtain the following equation:

$$A_t = a_0 + a_1 P_{t-1} + a_2 P_{t-2} + a_3 Z_t + a_4 A_{t-1} + v_t \qquad (3)$$

where $a_0 = \mu a_0, a_1 = \mu a_1, a_2 = \mu a_2, a_3 = \mu a_3, a_4 = (1-\mu), v_t = \mu u_t$ is the error term. a_0 is intercept term and α_1, α_2, α_3 are respectively the coefficient parameters of rubber prices, actual alternative crop prices and the lagged rubber planted area. Equation (3) asserts that the actual planted area of natural rubber in the current year is a function of one and two-year lags of rubber price, current alternative crop prices ($Z_t = CA_t$ is cassava price, MA_t is maize price and S_t is soybean price) and the lag of planted area.

As stand trees exist, the latex milk is mostly available during most of the year, except in early February to mid-March. The latex can be tapped anytime depending on the farmer's decision. He can tap or he can control the harvesting of latex at any point in time. At the same time as the yearly cutting panel in early March, other crops in the same area such as maize, soybean, mungbean and sesame are being planted. This can result in the lack of labor. Small holders use family members for their farm. The wage rate is an important factor in determining the average rubber yield per hectare a year. Consequently, almost all the rubber cultivators hire the tappers for latex collection and pay wages. When rubber price increases, farmers try many things to increase yield such as double tapping, rain protection and applying fertilizer. However, an increase in the price of the other crops has a negative impact on rubber yield as the farm labor switches work to these farms. Due to the limited data on tapper wage rate during the period of the study, we assume that alternative crop prices can be a proxy to the wage rate of latex milk collectors.

In this regard, Soependi (1993) noted that the small holder farmers tend to compete for the farmer's labor. Furthermore, they tap their rubber trees whenever they do not work in the other crop fields. Dowling (1979) found that farmers in the southern part of Thailand select rice as the alternative crop to natural rubber. Koma *et al.* (1998) found that the major source of family incomes (of 70% of the households) in Kampong Cham province was the cash income from soybean and mungbean production. To determine the average rubber yield per unit area, we may consider the rubber price and alternate prices as the main factors. There are also some factors that can affect rubber yield such as weather conditions. However, the only available set of data is the actual rainfall level.

Based on the information mentioned above, the average yield response of rubber is a function of the expected rubber price in the coming year and the other observable supply shifters. Hence, the rubber yield response can be expressed as:

$$Y_t = b_0 + b_1 P_t^* + b_2 Z_t + u_t \tag{4}$$

where Y_t is average rubber yield in period t, P_t^* is expected rubber price, Z_t are observable factors that can affect rubber yield in period t, and u_t is error term in period t. b_0 is constant term, and $b_1 b_2$ are the coefficient parameters of the expected rubber price and the observable variables, respectively. Since the expected rubber price is unrealized, we need a proxy by using other observable variables. In particular, we assume that, in each year, farmers revise the price they expect to prevail in the next year by using the proportion of the error that they make in predicting for last year's price. This assumption can be expressed mathematically as:

$$P_t^* - P_{t-1}^* = \lambda(P_{t-1} - P_{t-1}^*) \tag{5}$$

where λ is the coefficient of adaptive price expectation which is constant. It reflects the response of expectation of the observed price. Equation (5) implies that the producers adapt their expectation in the light of past experience and they learned from mistakes. This means price expectation is revised in each period by a fraction of λ. If λ approaches one, $P_t^* - P_{t-1}$, the price expectation is realized immediately. In contrast if λ is nearly zero, $P_t^* - P_{t-1}^*$-, the price expectation becomes static. We can rearrange the term of (4) by using a lag of one year period and substitute into (5). In this manner, we obtain:

$$Y_t = \beta_0 + \beta_1 P_{(t-1)} + \beta_2 Z_t - \beta_3 Z_t + \beta_4 R_t + \beta_5 Y_{(t-1)} + w_t \tag{6}$$

where

$$\beta_0 = \lambda b_0,\ \ \beta_1 = \lambda b_1,\ \ \beta_2 = b_2,\ \ \beta_3 = (1-\lambda) b_2,\ \ \beta_4 = (1-\lambda),\ \ w_t = u_{t-1} - (1-\lambda) u_{t-1}$$

β_0 is intercept and $\beta_1, \beta_2, \beta_3, \beta_4$ are the coefficient parameters of lags of rubber price, alternative crop prices, rainfall level and lags of rubber yield, respectively. Note that the sign of supply shifter Z_{t-1} which is the current alternative crop prices is negative. Thus, Equation (6) confirms that rubber yield is a function of last year rubber price, observable external factors and lag of rubber yield. We apply this model to the case of environmental conditions in Cambodia. Furthermore, we use alternative crop prices and rainfall instead of external variables. Consequently, the model of rubber yield response of natural rubber is defined as:

$$Y_t = \beta_0 + \beta_1 P_{t-1} + \beta_2 CA_t + \beta_3 MA_t + \beta_4 S_t + \beta_5 R_t + \beta_6 Y_{t-1} + w_t \quad (7)$$

Equation (7) states that average rubber yield per hectare a year is a function of lag of one-year of rubber price (P_{t-1}), current alternative crop prices (CA_t is the cassava price, MA_t is the maize price, and S_t is soybean price), actual amount of rainfall (R_t) and the yield of rubber in previous year (Y_{t-1}).

Data

The relevant data of rubber supply response in Cambodia from 1990-2008 are summarized in Table 1. The data include total planted area, rubber yield, crop producer prices and rainfall. We collected the data of the total planted area and average rubber yield from Directorate General of Rubber Plantation (DGRP) and Ministry of Agriculture, Forestry and Fisheries (MAFF). We used the data of crop producer prices from FAOSTAT. The information on rainfall was obtained from the Department of Meteorology of the Ministry of Water and Resource Management. From the average yield equation, we estimated the average rubber yield per hectare a year by using the data of rubber price, current rainfall and actual alternative crop prices. The data in Table 1 show that total planted area declined during the early 1990 to 2001 but increased nearly two times during the period 2005-2008.

Table 1 Data used in the analysis

Year	Planted area[1] (ha)	Rubber yield[1] (kg/ha)	Rubber price[2] (R/mt)	Soybean price[2] (R/mt)	Maize price[2] (R/mt)	Cassava price[2] (R/mt)	Rainfall[3] (mm/yr)
1990	51,160	678	420,600	165,000	53,000	52,000	1,539.74
1991	51,670	679	425,000	419,919	82,635	238,501	1,491.70
1992	50,835	559	445,324	440,000	90,000	249,333	1,556.77
1993	43,545	516	931,131	920,000	430,000	521,333	1,744.30
1994	42,817	718	961,494	950,000	390,000	538,333	1,765.70
1995	45,048	796	910,889	900,000	470,000	510,000	1,782.43
1996	45,538	989	1,012,100	1,000,000	400,000	450,000	1,719.47
1997	44,466	1,000	1,062,705	1,050,000	400,000	390,000	1,385.04
1998	42,625	998	1,093,070	1,080,000	590,000	700,000	1,381.34
1999	38,413	1,179	794,498	785,000	709,459	700,000	2,036.97
2000	36,825	1,197	1,199,340	1,185,000	625,000	629,000	1,748.54
2001	34,330	1,173	979,712	968,000	480,000	708,000	1,626.77

Table 1 (Continue)

2002	55,582	1,091	1,720,570	1,700,000	290,000	768,000	1,424.23
2003	53,527	1,163	1,303,584	1,288,000	384,000	650,000	1,445.27
2004	54,209	1,069	1,434,145	1,417,000	500,000	1,001,000	1,308.00
2005	60,406	969	1,275,246	1,260,000	554,000	1,078,000	1,527.40
2006	69,994	990	1,329,743	1,313,846	577,675	1,124,068	1,320.33
2007	82,059	1,081	1,512,891	1,613,694	609,475	1,141,584	1,529.30
2008	107,900	941	1,565,190	1,677,775	641,275	1,178,493	1,425.32

Note: "R=Riel" is Cambodian Currency Unit

Sources: [1] DGRP, [2] FAOSTAT, and [3] Department of Meteorology

Results and Discussion

The dependent variables are rubber planted area and the average rubber yield. The independent variables are rubber price, alternative crop prices, actual rainfall, the lags of dependent factors of planted area and rubber yield. Economic principle suggests that the estimated coefficients of explanatory variables are expected to be positive, except alternative crop price. A number of regressions are estimated along with the line of Equation (3) and (7).

The initial tested equation of planted area reveals that the coefficient of one-period lag of rubber price is negative while the coefficients of soybean and cassava price are positive. The problem occurs due to multicollinearity; in particular, soybean/cassava prices are highly related to rubber price. Furthermore, from the tested equation with one alternative crop price, we found that only the coefficient of maize price is consistent with economic theory. Moreover, the coefficient of last year rubber price is not statistically significant. Consequently, we decided to re-estimate the model by eliminating last year rubber price, soybean and cassava prices. By following this method, the best area response is given as:

$$\ln A_t = -2.2273 + 0.2731 \ln P_{t-2} - 0.1554 \ln MA_t + 1.04937 \ln A_{t-1} \quad (8)$$

$$(-1.2389) \quad (2.6803)^{*} \quad (-1.7525)^{**} \quad (6.7875)^{*}$$

$$R^2 = 0.83, \quad \bar{R}^2 = 0.79, \quad F = 21.4026, \quad D.W. = 1.8031, \quad SER = 0.1350$$

where * and ** are 0.01 and 0.10 levels of significance, respectively.

The coefficients of lagged two years rubber price, lagged planted area and current maize price are significant at 0.01 and 0.10 percent, respectively. This means that these variables can explain the new planting in variation of natural rubber hectarage. The relationship between dependent and independent variables is significant as shown by high F-value. The value of Durbin-Watson statistic of 1.8 indicates that there is no autocorrelation problem. Due to lag of dependent variable in the model, the Lagrange multiplier (LM) test is used to confirm the result. We found that there is no presence of autocorrelation/serial correlation.

All signs of the coefficients are consistent with the empirical observations. Therefore, new planted area of rubber tree has positive relationship with the rubber price but negative relationship with the maize price. Moreover, the estimated coefficients of the log-linear functional which is regarded as elasticities imply that a one percent increase in last two years rubber price leads to 0.27 percent increase in new planted area of the current year, while a one percent increase in current maize price results in a decrease in rubber planted of about 0.15 percent in rubber planted area. Furthermore, the impact of lag of planted area is the same as the effect of rubber price. However, the effect of maize price is negative and small (less than its own price). These results indicate that the new planted area of natural rubber gradually increases every year.

The rubber yield response model based on the adaptive price expectation was tested with some alternative crop prices. After carrying out several alternative trial equations, the model of average rubber yield per unit area selects the alternative crop prices. All estimated equations were tested with alternative crop prices. This is the same as area response. The results in all cases reveal that the coefficient of determinant R^2 or $\bar{R}^2$ are high enough. Their values are about 80 or 78 percent, respectively. There are high computed F-values as compared with F-statistics. D.W is 2.4, indicating no autocorrelation among the error terms. However, the estimated coefficients of independent variables show that only the coefficient of cassava price is consistent with the theory; it is negative and significant. The coefficients of either soybean or maize prices show positive signs and are insignificant. The equation that gives the best estimation to rubber yield response is selected. After carrying out several trial equations, the model of rubber yield per hectare a year in the log-linear functional form is given as:

$$\ln Y_t = -6.7864 + 0.421 \ln P_{t-1} - 0.164 \ln CA_t + 0.682 \ln R_t + 0.733 \ln Y_{t-1} \quad (9)$$

$$(-5.244)^* \quad (5.823)^* \quad (-2.986)^* \quad (5.113)^* \quad (10.560)^*$$

$R^2 = 0.93$, $\bar{R}^2 = 0.90$, F = 31.3611, D.W. = 2.3261, SER = 0.0774

The empirical results of Equation (10) state that around 90 percent of the variation in rubber yield per hectare a year is explained by lagged one year of rubber price, current cassava price, actual level of rainfall and lagged rubber yield, which is indicated by the $\bar{R}^2$. The F-statistic is highly significant at one percent level, confirming that explanatory variables help to explain variation in rubber yield improvement. The high value of D.W. statistic of 2.32 is greater than critical value, meaning that there is no autocorrelation. However, the LM test that was carried out to confirm the D.W. value suggests not significance of autocorrelation/ serial correlation among the error terms, i.e. no autocorrelation problem. The estimated coefficients of lagged rubber price, lagged yield, rainfall and cassava price variables are all statistically significant at 0.01, which is reported by computed t-values in parentheses.

Theory suggests that the positive signs of the coefficients would show that average yield per hectare of rubber trees moves in the same direction as those variables changed. In contrast, the negative sign indicates the inverse relationship. In addition, an increase/decrease of lagged rubber price, actual rainfall and lagged rubber yield lead to similarly increase/decrease as those variables changed. However, the negative sign of the cassava price coefficient implies that one percent increase in cassava price leads to 0.16 percent decrease in average rubber yield per hectare for the current year, and *vice versa*. The higher price of alternative crop planted in the same area tends to reduce the average rubber yield per unit area. On the other hand, the lower alternative crop prices planted in the center of rubber industry would be expected to increase rubber yield.

Both the partial adjustment and the adaptive price expectation models yield the same results. Thus, the long run elasticity of average yield of natural rubber with respect to lagged rubber price is estimated at 1.57. The long-run elasticity of rubber yield is more varied than the short run. These results are the same for area response. The long-run supply elasticity is greater than one which is considered as elastic. This implies that a one percent increase in the last year price of natural rubber leads to an increase of about 1.57 percent in rubber yield for the current year. The high value estimated at 1.57 suggests a high response of rubber yield to changes in its lagged price in the long run. The farmers have a strong incentive to respond to a change in price of the product from the rubber trees, even though the government ban on the export of unprocessed latex (or coagula) and rubber wood is still in force. If the government relaxes ban, it is likely that rubber producers will try to increase production to take advantage of the higher price. In turn, the government receives more tax. On the other hand, with the ban, the government loses tax revenue because coagula is smuggled across the border into Vietnam.

The absolute values of long-run supply elasticities were relatively greater than the short-run elasticities by five to twenty times. That indicates rubber farmers adjust their production planning in the long run more frequently than in the short run. Farmers do not respond much to changes in the price of natural rubber over a short-run production period because the area expansion is relatively fixed and constrained in the short term. The MAFF estimates the planted area has decreased from1990-2001 and strongly increased during the 2005-2008. This occurred because government had given the right to famers of land ownership for the Rubber Smallholder Development Project, Economic Land Concessions and privatization the State Owned Rubber Estates since the early 1990s. This made it possible for the rubber planters to make long term plans.

The positive signs of explanatory coefficients show that natural rubber supply of Cambodia moves in the same direction with the changes in the variables, while the negative sign reveals the inverse relationship. An increase (decrease) of rubber price will lead to increase (decrease) of new planted area, average rubber yield for the current year. In contrast, an increase in current maize price leads to a reduction in area expansion in the current year and *vice versa*. Furthermore, the increase in current cassava price results in the drop of the actual rubber yield in the current year and *vice versa*. Therefore, the higher prices of alternative crops, which use the same resource/planted in the same area as natural rubber, tend to cause a reduction in the rubber supply in the same year. Conversely, lower prices of alternative crops would lead to an increase in the rubber supply in Cambodia.

Conclusions

The empirical findings show that the expansion of rubber area planted and improvement in the rubber yield are affected by rubber price as the main factor. Other relevant factors such as rainfall and alternative crop prices also have effects on rubber supply. Moreover, some variables such as lag of planted area and lag of yield also relate to rubber supply. Other factors not included in the models such as government policies, circulars and regulations are assumed to have no effect on the supply of rubber in Cambodia. However, after the government had granted rights of ownership to farmers under the Economic Land Concessions, and privatized the Sate Owned Rubber Estates to smallholders planted area considerably expanded. Furthermore, the adoption of free market had motivated the rubber growers to increase rubber production by either expanding planted area or improving rubber yield or both, as they can decide to produce and sale freely in the market. The rubber cultivator responsiveness to the price of natural rubber is not so much (inelastic) in the short run (fixed factor of area/yield) but elastic in the long run. Thus, an increase in rubber production seems to be limited with price motivation alone. However, the growers have positive expectation of the high potential soil feature. Therefore, in order to increase rubber production, the rubber growers should be motivated by improved technology that increases rubber yield. Furthermore, the government should relax its ban on the export of certain rubber product forms. This might add to the incentive of rubber producers to increase rubber production by increasing planted area or improving rubber yield. The benefit to government is increased taxes.

Acknowledgements

The authors would like to thank the Thailand International Cooperation Agency (TICA) for the research funding.

References

Askari, H. and J. T. Cummings (eds.). 1976. **Agricultural Supply Response.** New York: Praeger Publisher.

Bateman, M. J. 1962. "Aggregate regional supply functions for Ghanaian cocoa 1946-1962." **Journal of Farm Economics** 47 (2): 384-401.

Behrman, J. and L. R. Klein. 1970. "Econometric growth models for the developing economy." In W. A. Eltis, M. F. Scott, and J. N. Wolfe (eds.). **A Survey of Agricultural Economics Literature.** London: Clarendon Press, 167-187.

Chan, F. K. W. 1962. "A preliminary study of the supply response of Malayan rubber estate between 1948-1959." **Malayan Economic Review** 7 (2): 77-94.

Directorate General of Rubber Plantation. 1980-2009. **Annual Statistics**. Phnom Penh.

Dowling, J. M. 1979. "The supply response of rubber in Thailand." **Southern Economic Journal** 45 (3): 795-804.

FAOSTAT. 2008. **Producer price** (Online). faostat.fao.org, June 25, 2008.

French, B. C., G. A. King, and D. D. Minami. 1985. "Planting and removal relationship for perennial crop: An application to cling peaches." **American Journal of Agricultural Economics** 67 (2): 215-223.

Hartley, M. J., M. Nerlove, and R. K. Peters, Jr. 1984. The supply response for rubber in Sri Lanka. **World Bank Staff Working Paper No. 657**. Washington, D.C.

________ . 1987. "An analysis of rubber supply in Sri Lanka." **American Journal of Agricultural Economics** 69 (4): 755-761.

Heady, E. O., C. B. Baker, H. G. Diesslin, E. Kehrberg, and S. Staniforth. 1958. **Agricultural Supply Functions.** Iowa: Iowa State University Press.

Koma, Y. S., P. Sokha, A. Pouliquen, and K. Makarady. 1998. **Family Rubber Plantation Development Project in Kampong Cham**. Research report submitted to Cambodian Education Development in Agriculture Center (CEDAC). Phnom Penh.

Ministry of Agriculture, Forestry and Fisheries. 1980-2009. **Annual Statistical Yearbook**. Phnom Penh.

Nerlove, M. 1958. "Estimates of the elasticities of supply of selected agricultural commodities." **Journal of Farm Economics** 38 (2): 496-509.

Soependi, I. Y. 1993. **Indonesian Natural Rubber: An Econometric Analysis of Its Supply and Foreign Import Demand.** Master Thesis of Science, Michigan State University.

Tomek, W. G. and K. L. Robinson. 1990. **Agricultural Product Prices.** 3rd ed. New York: Cornell University Press.

Wickens, M. R. and J. N. Greenfield. 1973. "The econometrics of agricultural supply: An application to the world coffee market." **Review Economics and Statistics** 55 (4): 433-440.