RESEARCH ARTICLE

Determinants of Supply Response of Coconut Cultivation in Sri Lanka

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ABSTRACT

Coconut (*Cocos nucifera* L) is a major plantation crop grown in Sri Lanka. The output has been mainly used for local consumption of fresh nuts, coconut-based industries within the country, and coconut exports. The instability of coconut supply seriously affects local as well as export market potentials. Identification of various factors and the extent to which those affected the current coconut supply have not been examined in the recent empirical work. This study examines the supply response of coconut in Sri Lanka, using Nerlovian Partial Adjustment model. The study used time series data of total coconut production, output price, rainfall, fertilizer amount, land extent, technology, and the presence of fertilizer subsidy for a period of 30 years (1985-2015) for the analysis. Among the different types of functional forms tested, the log-linear model was selected as the best fit model (R^2=0.894). The model was tested for autocorrelation and heteroscedasticity using the Durbin-Watson statistic and the Breusch-pagan test, respectively. The results revealed that the variables, i.e.two years lagged price, one year lagged rainfall, and two years lagged fertilizer amount affect the coconut production significantly ($p<0.05$). The short-run and long-run price elasticities were estimated for two years lagged output price.The output price is the most influential factor in short run with the elasticity of 0.33 (two year lagged price variables were considered) while rainfall is the most important determinant of coconut production in Sri Lanka. The study concludes that coconut production in the country tends to change as a response to the changes in coconut price both in the short-run and long-run. Further, rainfall and amount of fertilizer applied are the two main factors that determine the coconut supply in Sri Lanka.

Keywords: *Cocos nucifera*, Nerlovian partial adjustment model, Supply response

1. INTRODUCTION

The coconut tree (*Cocos nucifera* L) is a member of the family Arecaceae (palm family) and the only species of the genus Cocos. Coconut seed is the major item of coconut and botanically it is a drupe that gives multiple uses. Coconut palms are grown in more than 90 countries of the world, with an average total fresh nut production of 61 million tonnes per year. Sri Lanka is the fourth largest coconut producer in the world and it contributes 4.3% of total world coconut production (FAOSTAT, 2020).

Coconut is the largest plantation crop in Sri Lanka and the annual coconut production in 2022 was 335 million nuts. In 2022, contribution of coconut cultivation to the Gross Domestic Product (GDP) was 0.9%, while agricultural contribution to the GDP was 7.5% (Central Bank, 2022). Coconut plays an important role in developing the socio-economic condition of the people as it has multiple uses. It is an essential component of the Sri Lankan cuisine, nutrition, and rural livelihood as it is a major component in the Sri Lankan diet. An average household spends about 5.4 % of the total expenditure on food and drinks on coconut, which is the principal source of edible oil and fats (Department of Census and Statistics, 2019). The per capita coconut consumption including coconut oil is 122 nuts per year (Department of Census and Statistics, 2019). In addition, coconut-based industries contribute substantially to employment generation and foreign exchange earnings. Domestic fresh coconut consumption absorbs nearly 56% of the total production in the last five years and the rest is used for processed coconut products (Coconut Development Authority, 2021).

Annual coconut production in the past few years

revealed that coconut production in Sri Lanka is in slow growth and it is a serious impediment to the economic viability of the coconut industry. The average coconut yields have been stagnant over time but there is a substantial year-to-year variability due to climatic and other factors as application of fertilizer and mulching. This instability of coconut supply is a crucial issue in the coconut industry. These factors include product's own price, rainfall, fertilizer application, presence of fertilizer subsidy, and cultivated land extent. The short supply of coconut creates many consequences in the society as coconut is one of the main items in the Sri Lankan food basket, economy and livelihood. Reduction of coconut supply leads to increased coconut prices. Low production and high coconut prices badly affect the day to day consumption, coconut-based industries, and finally, it causes to reduce export income earnings from the coconut industry. On the other hand, it affects future production as producers also respond to the changes in coconut price.

Supply response explains the change in output due to changes in output price and other factors. It helps one to ascertain how farmers reallocate resources in response to the changes in relative price levels. Information on supply price elasticity allows the formulation of appropriate agricultural price policies and helps to understand and predict the short-run and long-run impact of price changes on production. When there is a crisis with production and supply of coconut, the government and the responsible parties take several short-term remedies but attention towards long-term measures in order to increase production is a must where factors affecting supply response plays an important role. However, recent literature on supply response of

coconut with the price and other factors are lacking. Hence, this research on coconut supply response is a timely vital need.

The general objective of this study is to examine the supply response of coconut production in Sri Lanka. Specifically, the study estimates both short-run and long-run price elasticities of fresh coconut production. Furthermore, it estimates the extent to which the factors namely fertilizer used, cultivated land area, rainfall, and presence of fertilizer subsidy affect the coconut production of Sri Lanka.

The remainder of the paper is structured as follows. Section II reviews literature on the supply response of perennial crops. Materials and methods used in the study are presented in the section III. Section IV explains and discusses the results of the empirical analysis while section V presents conclutions of the present study.

2. LITERATURE REVIEW

Supply response is the change in the quantity of a commodity output forward for sale when other things are not held constant and it is considered with the output response to a price change (Cochrane, 1955). Estimation of supply response in perennial crops needs special consideration as output flows over many years and in coconuts, it is about 60 years. The present output of a perennial crop is determined by the planting decisions in the past. Growers can change their production either by increasing land extent under cultivation or re-planting the senile palms. In perennial crops, there is a lag between inputs and outputs. In addition, technology improvement and the adoption of improved inputs increase production capacity. Hence, the present production capacity is the net effect of past

decisions that change the production capacity of the plantation (Kalaitzandonakes & Shonkwiler, 1992). Therefore, estimation of supply response of perennials must include the new plantings, removals, replanting, age composition, and the lag between inputs and output. However, the dearth of long-term time-series data on most of these factors compelled most of the studies on perennial supply response to use aggregate data.

Perennial crops have two distinctive features; i.e.(1) gestation period between planting and the first harvest which is determined by the biological nature of the crop and (2) significant adjustment cost of planting and removal which is determined by the decisions in the past, technology, availability of land, labour and capital (French & Matthews, 1971; Akiyama & Trivedi, 1987). The gestation period of coconut vary around 2-5 years depending on the variety.

The estimation of supply response to prices was advanced after the seminal work of Mark Nerlove (1958). This Nerlove model was primarily used for annual crops but later, it was modified to analyse perennial crops. The first attempt to adopt the dynamic Nerlove framework to study the supply response of perennial was employed by Bateman (1965) for cocoa in Ghana. The area is considered a function of discounted expected own and substitute prices. Similar Nerlovian models were used by Ady (1968) and Behrman (1968) for cocoa. The difference is that the desired acreage is modeled as a function of expected own and substitute prices instead of actual acreage. French and Mathews (1971) in their seminal paper on perennial supply response, developed a theory to explain new plantings and acreage adjustment. This is empirically applied to the asparagus industry in the USA and specified

acreage was taken as a function of lagged own price and lagged acreage. The above studies laid a theoretical foundation for the analysis of supply response for perennials. This model was extended later with modifications.

Samarajeewa *et al.,* (2001) estimated the supply response of coconut production in Sri Lanka. The Nerlovian partial adjustment model was used to estimate the regression coefficient of a specific equation. The model was corrected for autocorrelation and heteroscedasticity to obtain consistent results.The results revealed that the coconut producers respond to output price changes significantly in the short-run than in the long-run. Two-year lagged price, one-year lag rainfall, and cost of production of the current year are the crucial factors that affect coconut production.

Leaver (2004) evaluated the supply response of Tobacco in Zimbabwe. The analysis was carried out using the data from 1938 to 2000. A modified form of the Nerlovian model was used in this study to prevent various problems that arise from the statistical estimation of the original Nerlovian model. The results show that tobacco farmers are highly unresponsive to price changes.

Karunakaran & Gangadharan (2014) estimated the supply response of coconut in Kerala. Nerlovian supply response model was used in this study and the farmers' decisions are discussed in terms of area response and yield. The analysis revealed that the irrigated area, rainfall, and price risk factors are the significant variables affecting the area allocation for coconut in Kerala and the crop's yield response, irrigated area, rainfall and expected price risk are the most significant variables.

3. MATERIALS AND METHODS

3.1. Data

According to the objectives of the study, the supply response of coconut was analyzed for a period of 31 years from 1985 to 2015. Secondary data were obtained from the annual reports of Central Bank, Coconut Statistics of the Coconut Development Authority and General Reports of Census of Agriculture. Use of the nominal output price does not make economic sense if inflation is high, since farmers will be interested in the actual purchasing power of their money and as a result will respond to changes in real output prices rather than changes in nominal prices (Leaver, 2004). Accordingly, as this study uses the time series data of price, they need to be adjusted for inflation. Hence nominal prices of coconut were converted into real prices using the Wholesale Price Index (WPI) of each year using the following formula.

$$Real\ price_z = Nominal\ price_z \times Adjustment\ factor \qquad (1)$$

The adjustment factor is formed using WPI measures as follows.

$$Real\ price_z = Nominal\ price_z \times \frac{WPI_{Base\ year}}{WPI_z} \qquad (2)$$

Where,

Z = year considered

3.2. The Model

Supply response analyses were conducted in two frameworks: (1) the Nerlovian model which facilitates a level of adjustment and speed of adjustment of actual acreage and desired acreage and (2) supply function derived from profit-maximizing framework (Dasgupta, 2009; Vrankic & Krpan, 2017). Joint estimation of output supply and input demand is used in the latter method. This type of analysis requires information on all input prices. In addition, market intervention for the input market is very common in Sri Lanka and the input market for agricultural products are not competitive. These factors led to the selection of the Nerlovian partial adjustment model for this analysis and supply response was measured in terms of quantity response to prices.

According to Nerlove, the desired output can be expressed as a function of the expected price and exogenous shifters (Cummings & Askari, 1977).

$$Q_t^* = a + bP_t^* + cZ_t \tag{3}$$

where, Q_t^* is desired output in period t, P_t^* expected price in period t, and Z_t is a set of exogenous shifters in period t such as technology change, weather condition etc.

Actual output may differ from the desired because of the adjustment lags of variable factors. Therefore, it is assumed that the actual output would only be a fraction d of the desired output.

$$Q_t - Q_{t-1} = d(Q_t^* - Q_{t-1}) \tag{4}$$

where, Q_t is the actual output in period t, Q_{t-1} is the actual output in period $t-1$, and d is the adjustment coefficient of output. Its value lies between 0 and 1.

The farmers' expected price at harvest time can be observed. So, it needs to describe how the decision-makers form expectations based on the knowledge of actual and past prices and other observable information. It is assumed that farmers remember in their memory the magnitude of the mistakes they made in the previous period and learned by adjusting the difference between the actual and expected price in *t-1* by a fraction λ.

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

The adjustment parameter λ is the expectation coefficient of price. It measures the speed of adjustment of the expected price and actual price and the value lies between 0 and 1. The value closer to 1 indicates the faster the speed of adjustment.

In order to estimate the supply response using the Nerlovian model, it is necessary to eliminate the unobservable variables associated with expected price and the desired output from equations (3) to (5) (Braulke, 1982). By eliminating these variables, the estimating or "reduced form" Nerlovian equation is achieved.

Using the values of P_t^* and Q_t^* from equation 4 and 5, the equation 3 can be written as;

$$Q_t = ad\lambda + bd\lambda P_{t-1} + (1-d) + (1-\lambda) Q_{t-1} + cdZ_t \tag{6}$$

$$Q_t = A_0 + A_1 P_{t-1} + A_2 Q_{t-1} + A_3 Z_t \tag{7}$$

where, A_0 is $ad\lambda$, A_1 is $bd\lambda$, A_2 is $(1-d) + (1-\lambda)$, and A_3 is cd.

The biological nature of the coconut crop identifies different time lags between dependent and independent variables. The study uses time-series data to predict the current values of the dependent variable (coconut supply) based on both the current values and the lagged (past period) values of explanatory variables. Hence,

the distributed lag model was used for the analysis. Dependent variable Y was determined by the weighted sum of the past values (lagged) of independent variables, Xs (Almon, 1965). It defined the pattern of how Xs affect Y over time.

According to this model, the short-run and long-run price elasticities of supply are computed simultaneously. Elasticity formulas for the linear model can be expressed as follows. However, this changes according to the functional form that is used.

$$Short\text{-}run\ Price\ Elasticity = A_1 \times \frac{P_{t\text{-}1}\ mean}{Q_{t\text{-}1}\ mean} \qquad (8)$$

$$Long\text{-}run\ Price\ Elasticity = \frac{A_1}{1\text{-}A_2} \times \frac{P_{t\text{-}1}\ mean}{Q_{t\text{-}1}\ mean} \qquad (9)$$

Short - run Price Elasticity = A1 ×Pt-1 mean Qt-1 mean

The empirical model selected for the study is represented by the following function in the linerar form but the different models will be estimated and the best fit model is selected.

$$Q_t = a + bQ_{(t\text{-}p)} + bP_{(t\text{-}q)} + cFA_{(t\text{-}r)} + dRF_{(t\text{-}s)} + eL_t + gFS_t + hT + U(10)$$

Where,

Q_t = Production (nuts in million)

P = Real price of coconut (Rs/1000 nuts)

FA = Fertilizer amount (tonnes)

RF = Rainfall (mm)

L = Land extent (ha)

FS = Presence of fertilizer subsidy (Dummy variable; given=1 or zero otherwise)

T = Time (years)

U = Error term

$(t\text{-}p), (t\text{-}q), (t\text{-}r), (t\text{-}s)$ = Time lags

a, b, c, d, e, g, h = Coefficients of variables

It is assumed that the desired level of output in time t is a function of lagged output and lagged forms of output price, rainfall, land extent, presence of fertilizer subsidy, time, and the fertilizer amount.

The total coconut production was regressed with independent variables in the model to uncover the best fit variables. Different types of functional forms such as linear, log-linear, lin-log, and log-log were tested. The fitted model was estimated by the Ordinary Least Square (OLS) test using the Stata version 14.2 statistical software. An autocorrelation test was conducted using the Durbin-Watson statistic to test the autocorrelation effect. At the same time, the Bresch-pagan/Cook-Weisberg test was conducted to test for heteroskedasticity.

4. RESULTS AND DISCUSSION

The suitability of the models were judged based on Akaike's Information Criterion (AIC), coefficient of determination (R^2), expected signs of the estimated parameters, and by the significance of the independent variables. Accordingly, the Log-linear model was selected as the best model.

The regression results of the Log-linear model are presented in Table 1. Given test statistics for overall significance of the model follow F-distribution and it appeared that the estimations are highly significant. The R^2 value indicates that approximately 89% of the variation is explained by the model. Except for one year lagged and three year lagged fertilizer amount applied, all the other variables bear expected signs and hence they are in the right direction and in lined with the theoretical justifications.

theoretical justifications. The results show that two year lagged price, one year lagged rainfall, and two year lagged fertilizer amount are statistically significant at a 5% significant level and show a positive relationship with coconut production.

Table 1: Coefficient estimates of Log-linear model

Variables	Coefficient estimates	*t* Statistic	*P*Value
$Q_{(t-1)}$	0.164e-04	1.22	0.828
$P_{(t-2)}$	0.303e-04	2.36	0.035*
$RF_{(t-1)}$	0.122e-03	2.91	0.012*
$FA_{(t-2)}$	0.532e-07	2.59	0.022*
L_t	0.37e09	0.08	0.941
FS_t	0.508376	1.91	0.078
T	0.001861	0.54	0.598
Cons	6.585567	22.74	0.000

*indicates significant at 5% level.

Table 2: Short-run and Long-run Elasticities

Variables	Short-run Elasticity	Long-run Elasticity
$P_{(t-2)}$	0.33	0.08
$RF_{(t-1)}$	0.23	0.32
$FA_{(t-2)}$	0.18	0.01

Short-run elasticity of two year lagged coconut price was 0.33 (Table 2). It implies that when there is a rise in the current coconut price by one percent, the coconut production may increase by 0.33% in the year after next year. The short run and long run elasticities of one-year lagged rainfall was reported as 0.23 and 0.01 respectively. It indicates that if there is an increase in rainfall by one percent in the current year, coconut production will increase by 0.23% year after. The elasticity of two year lagged fertilizer amount is 0.18 indicating one percent increased fertilizer application in the current year results in a 0.18% rise in coconut production after two years. As supply elasticities of coconut price, rainfall, and fertilizer amount are less than one, it can be concluded that they are inelastic.

Results indicate that the coconut supply of Sri Lanka is responsive to price changes. As there is no any fixed level of coconut price in Sri Lanka, it has been fluctuating in a broad range for many years. When supply of a commodity is decreased, its price is increased and this is applied to coconuts as well. Although the coconut price are increased , consumers tend to purchase as it is a major component in Sri Lankan food items.

Rainfall is one of the most influential factors on coconut supply of Sri Lanka. A well-distributed mean annual rainfall of between 1,500-2,000 mm is considered to be favorable for the cultivation of coconut. According to the summary statistics, within the past 31 years, rainfall has fluctuated between a range of 1,363.33-2,288.5 mm. Hence, coconut supply also fluctuated accordingly. The coconut bunch goes through a cycle of development lasting about 36 months before it is ready to harvest. The development of nuts takes place during the last twelve months after the opening of the inflorescence (Child, 1974). During the nut developing period, especially three months after flower opening of the coconut as well as three months before flower opening are very sensitive to major climatic elements namely rainfall and temperature. Hence, the coconut supply depends on the change of rainfall significantly. Effect of current weather is usually reflected on the yields of the following year due to its lagged effects.

Use of fertilizer is one of the effective short term method of increasing coconut production in Sri Lanka and it is one of the main factors which affects yield in the short run under the control of farmer (Silva, 1981). The removal of nuts from estates removes a considerable amount of nutrition from coconut plantations. In addition to the removal by palms, soil nutrients can be lost by leaching, runoff, erosion, and uptake by weeds.

The above processes lead to the depletion of essential plant nutrients in the soil, which causes a gradual decline of nut yield. Therefore, soils in coconut plantations should be enriched with nitrogen (urea), phosphorus (Eppawala rock phosphate), potassium (muriate of potash), and magnesium (dolamite) which are the major nutrients that remove from above mentioned processes (Mahindapala and Pinto,1986). The nutrient requirement of young coconut palms and adult palms are different and therefore different fertilizer recommendations are made to them separately. Thus, coconut farmers tend to change the coconut supply by changing the fertilizer application whenever necessary. Summary statistics show a greater variation of fertilizer application with the minimum amount of 5,456 tons to maximum amount of 47,114 tons within the past 31 years by resulting in a supply response of coconut to change of fertilizer application. Due to the perennial nature of coconut, and the rate of release of nutrients from fertilizer, it takes two years to increase the coconut supply as a response to the increase in fertilizer application.

Data were tested for heteroskedasticity and autocorrelation using Breuch-pagan test and Durbin-Watson statistics, respectively. The results of these tests are presented in Table 3 and 4, respectively.

Table 3: Results of Heteroskedasticity test

Breusch-pagan / Cook-Weisberg test for heteroskedasticity H0 : Constant variance Variables : fitted values of coconut production (nuts/mn)		
Chi2(1)	=	0.05
Prob > chi2	=	0.8159

The null hypothesis is not rejected, as the probability value is greater than the conventional trigger point ($\alpha = 0.05$) indicating that the variance is constant and data are free from heteroskedasticity.

Table 4: Results of Durbin-Watson statistics

Number of gaps in sample	:	2
Durbin-Watson d-statistic (14, 20)	=	2.118134

A rule of thumb is that test statistic values in the range of 1.5 to 2.5 are relatively normal. As the Durbin-Watson statistic is close to two, there is no autocorrelation.The error terms of data do not show a significant correlation with each other.

5. CONCLUSIONS AND SUGGESTIONS

This study investigated the supply response of coconut to price fluctuations and changes in rainfall, amount of fertilizer applied, presence of fertilizer subsidy, technology, and the land extent. The findings of this study revealed that coconut production responds significantly to output price fluctuations and it is the most influential factor on coconut production in Sri Lanka. The coconut supply of Sri Lanka positively responds to two years lagged coconut prices. Among the other factors that significantly affect supply response of coconut output in Sri Lanka are one-year lagged rainfall, and two-year lagged fertilizer amount. All these factors are positively affecting coconut production and the higher the above factors, the greater the supply of coconut in Sri Lanka.

The elasticity of two-year lagged coconut price is 0.33 in the short run while it is 0.08 in the long run.The elasticity of one-year lagged rainfall is 0.23 in the short run while it is 0.32 in the long run. The elasticity of the two-year lagged fertilizer amount is 0.18 in the short run while it is 0.01 in the long run.

The findings can be used by the government and policymakers for price setting for coconut and to implement agricultural and income policies to encourage greater production of coconut in the country.

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