DOI: http://doi.org/10.4038/sjae.v23i1.4661

An Empirical Analysis of the Supply Response of Coconut by Vector Error Correction Approach: Cross Country Comparison

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ABSTRACT

This study estimates the output supply response of coconut in major producing countries using the cointegration approach. Regional variations in the domestic coconut production in Sri Lanka, India (represented by the state of Kerala), and the Philippines were captured by applying a Vector Error Correction Model (VECM). National aggregate time series data for the period 1970-2019 were used in the analysis. The empirical results show that unique long-run equilibrium relationships exist among coconut production, the coconut price, and the climate variable in three individual markets and the panel estimation. The regional disparities are revealed by the short-run dynamics throughout the analysis. Altogether, the econometric estimates provide strong evidence that the coconut producers respond rationally to the changes in own price and other supply determinants. However, both short and long-run price elasticities of the coconut supply response are rather low amidst its significance, suggesting that any pricing policy requires a comparatively long lead time for it to become effective in accelerating production. Furthermore, the estimated panel VECM can be further developed and validated to be used as a tool to analyze the regional deviances for assisting the policymakers in making comprehensive strategies to ensure the industry's long-term sustainability.

Keywords: *Coconut, Cointegration, Supply response, Vector Error Correction Model*

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Introduction

Coconut (*Cocos nucifera L.*) is a versatile perennial tree crop with very important food value and endless uses which pave the way for the emergence of a diversified set of industrial activities. Owing to the multifarious uses of different parts of the palm, it forms an integral component of the social, economic, and cultural lives of nearly 80 million people in 92 countries (Naveena, *et al*., 2014). The economic importance of the coconut industry is manifold as well as a vital source of export earnings for the coconut-producing countries. Coconut production is heavily confined to the Asia and Pacific regions whereas the consumption is dispersed around the globe. India, Indonesia and the Philippines are the major coconut producers in the world. Sri Lanka is the fourth-largest producer of coconut and usually accounts for some 5% of the world's coconut production (APCC, 2020). The Sri Lankan coconut industry has advanced over the years, and it substantially contributes to the well-being and livelihood of people as well as to the domestic economy.

Coconut occupies about 20% of the arable lands of the country, around 443,000 hectares (Department of Census and Statistics, 2014) which accounts for 4% of the world area of coconut. The predominant smallholding sector provides 70% of the total annual coconut production of the country and accounts for approximately, 85% of the area under coconut. The rest of the area comes under the state sector. The coconut sector is also an important source of employment where more than a hundred thousand farm households work directly, and more are employed in related processing industries. It contributes about 0.7% to the Gross Domestic Product (GDP) (Central bank of Sri Lanka, 2021), and 6.83% to the total merchandise exports of the country (Export Development Board, 2021).

The history of the domestic coconut industry is often coupled with low remunerative returns to growers which then diminishes their reinvestment capacity in the long run. Hence over the past few decades, the country is experiencing a stagnating production which ranges between 2,500-3,000 million nuts. The situation has further worsened by the shrinking of the area under coconut especially in the wet zone due to urbanization and the land fragmentation in the coconut triangle where 67% of the coconut lands are concentrated. Moreover, the market share of desiccated coconut and coconut oil, which are the two major traditional export products of coconut has eroded in the world market due to emerging competitors. Given the above scenario, the government is currently in a process of revamping the domestic coconut industry. Accordingly, the government has set out different strategies to enhance the productivity and competitiveness and to modernize the predominant smallholding sector in line with the principal objectives of the coconut sector including i) Increasing the productivity of existing coconut lands, ii) Increasing the incomes of the primary producers and the processors and iii) Increasing export earnings which remained unchanged over nearly a half-century. Successive governments have attempted the task of ensuring a remunerative price for growers from several angles. i.e., price stabilization schemes, measures of increasing competition, financial aids, and cost support subsidies, etc. The infrastructure facilities and other service capabilities have also been improved.

Despite all these efforts, previous studies on the coconut sector have identified several key challenges that continue to plague the Sri Lankan coconut industry, notably including declining overall yields and output of coconut, a reduction in coconut acreage, the rising cost of production, abandonment of large estates due to low returns, etc. Hence, revisiting the success and effectiveness of the policies in the coconut sector and allocation of the farm resources is of crucial importance. This could best be examined by analyzing and quantifying output response to changes in input prices and other related variables (Nerlove and Bachman, 1960; Akiyama and Trivedi, 1987; Devadoss and Luckstead, 2010; Mustafa, *et al.*, 2016). Therefore, Supply response analysis or analyzing the behaviour of the producers is one of the most commonly used tools to evaluate the success and effectiveness of pricing policies and it is critical to resource allocation as well. Moreover, it helps to ascertain the profitability of agricultural production and provides useful insights into the effect of government policies on the supply responsiveness of farmers (Devadoss and Luckstead, 2010).

Based on the above discussion, this study aims to examine the short-run and long-run relationship between the coconut supply and the factors that determine coconut supply in Sri Lanka, and of particular interest is to measure their magnitudes. Since the coconut market can be better represented by a group of interconnected local markets or regions rather than a national aggregate, it is further intended to investigate the links between regional coconut production and other related determinants for a panel of three major coconut-producing countries including Sri Lanka, India (represented by the State of Kerala), and the Philippines.

Literature Review

Even though the literature on the agricultural supply response has occupied a fundamental role in agricultural economics in the last century (Nerlove and Bachman, 1960), supply response for perennial crops, unlike for annual crops, has received limited attention in the literature because of modelling complexity and data constraints. The perennial crop supply is vastly different from the annual crop supply. Previous studies on agricultural supply response have distinguished the supply response of annual crops from perennials due to certain distinctive characteristics of plantation crops. Nerlove and Bachman (1960); French and Mathews (1971); Trivedi, (1986); Akiyama and Trivedi (1987); Kalaitzandonakes and Shonkwiler(1992) and Elnagheeb and Florkowski, (1993), have discussed these specific characters in detail. Firstly, there is a biologically determined gestation period between planting and initial harvesting which is then followed by an extended period of productivity. There is a gradual decline in production and once it comes to the final productivity decline, they are removed. Secondly, removal and replanting decisions are restricted by past decisions, technology, and the availability of land, labour, and capital coupled with significant adjustment costs. The implications of the above characters are threefold. First, perennial crop production is dynamic, and production depends on the biologically determined life cycle and in particular on the total tree stock, different maturities, and the availability of new improved varieties. Second, current production depends not only on current input usage but also on previous. Third, perennial tree crops are long-term investments and farmers have to invest using long-term planning strategies. Therefore, the supply response models should explain the planting process (new plantings, removals, and replacement of plants), the age composition of the stands, and the lag involved between the input and output (Kumar and Sharma, 2006).

Empirical studies on aggregate supply response of perennial crops first appeared in the literature in the early 1960s (Kalaitzandonakes and Shonkwiler, 1992). French and Bressler developed the first profound perennial acreage response model for lemon production in terms of total plantings and removals (French and Bressler, 1962). Bateman (1965), who attempted to examine the supply response of cocoa in Ghana appears to be one of the first to adopt Nerlove's (1958) framework; a dynamic model, stating that output is a function of expected price, output (area) adjustment, and some exogenous variables, for studying perennials. Assuming that the expectations were adaptive, Bateman (1965) applied Nerlove's adaptive price expectation framework to the Ghanaian cocoa industry in five regions covering the period 1946-1962. He argued that as the planting decisions are based on expectations, income, and maintenance cost which spread over the life span of the considered perennial tree crop, farmers always try to maximize the present value of their profit concerning the area planted. Hence area can be described as a function of the present value of expected prices, expected marginal cost, and expected marginal and total yield. Further assuming that producer price is the most important factor affecting income expectations, he comes up with the conclusion that area is a function of discounted expected and substitute prices and arrived at a single equation reduced form estimation of cocoa supply. This was followed by Behram (1968) who attempted to examine the production of cocoa in some major producing countries by employing the Nerlovian partial adjustment approach. Ady (1968) has used a similar framework for cocoa, however instead of examining actual acreage, the desired acreage is modelled as a function of expected own and substitute prices.

French and Mathews (1971) attempted to enlarge the concepts utilized in the previous applied studies to broaden the analytical framework for estimating perennial crop supply response. They have specified separate equations describing five major components namely i) desired acreage and production by growers, ii) new planting, iii) acreage removed, iv) change in acreage, and v) producer expectations. Nerlovian partial adjustment model was adopted for a new planting component where acreage is gradually adjusted to its desired level. The model was applied to the US asparagus industry. However, they were unable to estimate the system by simultaneous equation and, instead of a single form, a reduced form model was estimated. This equation describes the total change in bearing acreage from one year to the next as a function of the current price, lagged price, and lagged acreage. However, the structural parameters in the model were under-identified. Extensions of this model were employed in later studies by Alston, *et al.,* (1980) on Australian orange industry; Bushnell and King, (1986) on almond; Petersen, (1993) on apple; Elnagheeb and Florkowski, (1993) on the pecan industry; Carman and Craft, (1998) on avocado; Devadoss and Luckstead, (2010) on apple, etc.

Hartley, *et al.,* (1987) and Akiyama and Trivedi, (1987) were the first to note that there is a qualitative difference between new planting and replanting investment decisions. Hartley, *et al.,* (1987) estimated the supply response of rubber production in Sri Lanka while Akiyama and Trivedi estimated the tea supply response in major tea growing countries including India, Sri Lanka, and Kenya. In both of these studies, estimation of individual structural relationships was facilitated by the availability of detailed time series data on new plantings and removals of tea and rubber.

Studies that analyze the supply response of coconut in producing countries are relatively few. Silva (1979) attempted to model the coconut supply response for Sri Lanka. He argues that similar to other perennial crops, decisions on planting coconuts are a function of the long-term investment prospects, which depend on expected productivity and prices not only of coconuts but also of associated crops which can be intercropped with palms. In the short run wherein bearing acreage remains constant the quantity produced depends on the area harvested and the yield of the area harvested since all the bearing acreage may not be harvested at any one time. In the long run, where the productive capacity is changing, a change in mature acreage would be mainly due to the lagged response of new plantings and replanting, stemming from the profitability of investments. However, as the data on acreage planted to coconut, bearing and harvested acreages, senile acreage, and removals were not available he was unable to estimate the price responsiveness of the aggregate output of coconuts.

Dumayas, (1983) attempted to model the supply response of coconut in the Philippines. In this study, supply response was estimated by two components namely i) bearing tree equation; where the total number of bearing trees in the current year depends on the expected own price (the price of copra) and expected price of competing goods, and ii) yield equation where copra yield per bearing tree depends on input prices, climate, and other related variables. Karunakaran and Gangadharan’s (2014) study on the supply response of coconut cultivation in Kerala is one of the most recent studies. In this study, they have employed the Nerlovian lagged adjustment model to discuss the farmers’ decision in terms of area response and yield response.

The importance of the dynamic structure of agricultural supply functions has long been recognized. However, many of the early empirical studies have employed ordinary least squares and the work pioneered by Nerlove (1958). Nerlove's partial adjustment and/or adaptive expectation framework, though not without shortcomings, has been widely adopted and applied in several early empirical studies (Baltas, 1987) and nevertheless, it has long remained as a useful analytical tool for investigating the supply behaviour of farmers. This has widely been used particularly due to its underlying assumptions that allow a straightforward application of the model to make and as such a model appeared to be worked well in different products in several empirical studies.

Criticism of Nerlove's framework has mainly focused on two issues. On one hand, it has an inadequate theoretical basis as these models imply restrictive geometrically declining lag structures, and the use of ad hoc lag structures may also capture dynamics inadequately (Soontaranurak and Dawson, 2015). Further, the complications arise in the empirical analysis due to the specification of "unobserved expectations" and "desired levels of acreage" (Knapp and Konyar, 1991; Kalaitzandonakes and Shonkwiler, 1992). On the other hand, statistical estimation problems may arise when the Ordinary Least Square (OLS) method is used. Most time series data use in economic studies are trended over time and OLS regressions between trended series may produce significant but spurious results (Granger and Newbold, 1974). This spurious regression is a common problem in many of these studies. More recent studies have used co-integration and vector error correction approach since they provide more general dynamic structures and overcome the criticism of restrictive lag structure and spurious regression. Some of these studies include; Alias and Tang, (2005) to examine the supply of Palm oil in Malaysia; Mesike, *et al.,* (2010) to examine rubber supply response in Nigeria; Darkwah and Verter, (2014) to examine cocoa bean supply in Ghana; Wani, *et al.*, (2015) to analyze supply response of apples and pears in Jammu and Kashmir, India; Soontaranurak and Dawson, (2015) to analyze rubber acreage supply response in Thailand and Mustafa, *et al.*, (2016) to examine the supply response of rubber in Malaysia. The general conclusion that has been drawn in all these studies is that cointegration and VECM approach as they exhibit more general dynamic structures than the Nerlovian models. A summary of some of the studies that investigate the supply response of perennial crops is shown in Table 1

Table 1. A summary of selected studies of supply response of perennial crops

Author	Period of study	Crop	Method(equation)	Dependent variable	Short-run elasticity	Long-run elasticity
Dumayas (1983)	1960-1980	Coconut	OLS	No. of bearing trees	0.12	
Talib (1988)	1961-1985	Palm oil	OLS	Area planted	0.72	1.48
Akiyama and Trivedi (1987)	1970-1980	Tea	OLS	Area planted	0.03	
Samarappulin and Bogahawatta (1993)	1970-1990	Rubber	OLS	Area planted	0.14	
Sreeja (1998)	1960-1996	Coconut	Nerlove's lag adjustment -OLS	Output Area planted	Area: 0.34 Output: 1.24	
Alias, *et al*. (2001)	1977-1997	Palm oil, Rubber, Cocoa	Cointegration	Output		Rubber: 0.18
Samarajeewa (2002)	1956-2000	Coconut	Simultaneous- SUR	Output	0.19	
Pipitkul (2004)	1975-2002	Rubber	2SLS (Simultaneous)	Output	0.08	
Kumar and Sharma (2006)	1974-1999	Rubber, tea, coffee	Nerlove's lag adjustment -OLS	Output	Rubber: 0.09 coffee: 0.25 Tea: 0.1	
				Area planted		Rubber: 1.25
Laajimi, *et al*. (2008)	1980-2004	Peaches	OLS	Area planted Output	0.1 0.07	 0.13
Mesike, *et al*. (2010)	1970-2018	Rubber	VECM	Output	0.373	0.20
Soontaranurak and Dawson (2015)	1962-2009	Rubber	VECM	Area planted	0.04	2.24
Wani, *et al*., (2015)	1981-2013	Apple, Pears	VECM	Output	Apple: 0.32, Pears: 0.03	Apple: 0.33 Pears: 0.28
Mustafa, *et al*., (2016)	1990-2014	Rubber	VECM	Area planted	0.04	0.77
Abeysekara, *et al*., (2020)	1956-2017	Coconut	Simultaneous - SUR	Output	0.11	

Note: **OLS**-Ordinary Least Square; **ECM**-Error Correction Model; **VECM**-Vector Error Correction Model; **SUR**-Seemingly Unrelated Regression

Empirical Approach

The theoretical literature on perennial crop supply response suggests that coconut supply is determined by its own price, competing crop prices, input prices as well as other non-price factors. The farmers' responsiveness can be estimated for either total production (output)/yield or the planted acreage. On one hand, the planted acreage is preferred in many studies of perennial crop supply response as it measures intended supply and it is more subjected to the control of the farmers unlike the output which is subjected to more random variations than acreage due to uncontrollable yield determine factors (Akiyama and Trivedi, 1987; Samarappuli and Bogahawatta, 1993; Soontaranurak and Dawson, 2015; Mustafa, *et al.,* 2016). On the other hand, one can argue that the appropriate measure would be the volume of output produced since the level of output can easily change without changes in acreage (Mesike, *et al.,* 2010; Ebi and Ape, 2014; Wani, *et al.,* 2015). However, due to the non-availability of data for several variables over the considered time period, the long-run equilibrium supply response of coconut is estimated in the simple form in this study as follows.

$$CP_t = \beta_0 + \beta_1 NP_t + \beta_2 RF_t + \beta_3\ AP_{t-7}\mu_t \dots\dots\dots\dots\dots (1)$$

Where CP is the coconut production in terms of fresh nuts which is the raw output of coconut, RP is the own price of fresh nut in real term and RF is the climatic variable which is represented by rainfall as coconut is widely considered as a rainfed crop (Child, 1974), AP is the new/replanting acreage seven years earlier as the gestation period of a typical coconut palm is 5-7 years and is represented by the percentage share of the total coconut acreage seven years earlier. All variables are expressed in natural logarithm, and μ is a disturbance term.

One of the key assumptions underlying classical regression is that the variables are stationary. However, most economic time series are non-stationary, hence OLS regression between such time series generates spurious results (Granger and Newbold, 1974). To render such series into stationary, those must be first differenced. Therefore, analyses of time series require a prior investigation of the stochastic properties of the series. The first step is to carry out a unit root test to determine whether a variable is stationary or otherwise they must be first differenced to render them stationary. When the variables are integrated into order one, I (1), the series are cointegrated. Cointegration implies the existence of a long-run equilibrium relationship which can only exist when at least two variables are integrated of the same order (Granger, 1981). Similarly, it implies that long-run co-movement of variables such that their linear combination is stationary even if individual time series are non-stationary. In the first step, a series of stationary structures were analyzed by employing relevant unit root tests. At the next stage, cointegration tests were applied to ascertain the presence of a long-run equilibrium relationship among the variables of interest. If the deviation from the long-run equilibrium path is bounded or cointegration is confirmed, Engle and Granger (1987) showed that the variables can be represented in a dynamic vector error-error correction model (VECM).

This study employs the procedure proposed by Johansen (1988) which is based on the Vector Autoregressive (VAR) framework. The associated VECM of the VAR-based test can be represented as,

$$\Delta Y_t = \alpha_0 + \sum_{i=1}^{k} \alpha_1 \Delta Y_{t-1} + \pi Y_{t-1} + \varepsilon_t \dots\dots\dots\dots\dots\dots (2)$$

Where Y is an n×1 vector of I (1), Δ is the first difference operator such that ΔYt= Yt-Yt-1, k is the system lag order and ε is the error term with zero mean, constant variance, and zero covariance. Within this framework, information about the number of cointegrating vectors denoted by r is determined by the rank of π. Based on establishing r distinct cointegrating vectors, π can be decomposed into two n×r coefficient matrices λ and β. In other words, π = λ θ and thus,

$$\Delta Y_t = \alpha_0 + \sum_{i=1}^{k} \alpha_1 \Delta Y_{t-1} + \lambda(\theta Y_{t-1}) + \varepsilon_i \dots\dots\dots\dots\dots (3)$$

Where λ measures the speed of adjustment, β is a vector of long-run parameters, and the term θY_(t-1) is the error correction term representing the deviation from the long-run equilibrium.

Based on establishing the presence of a cointegrating vector, the VECM model for coconut is estimated as follows.

$$\Delta CP_t = \beta_3 + \beta_4 \Delta CP_{t-1} + \beta_5 \Delta NP_{t-1} + \beta_6 \Delta RF_{t-1} + \lambda(CP_t - \theta_0 -$$

$$\theta_1 CP_{t-1} - \theta_2 NP_{t-1} - \theta_3 RF_{t-1} - \theta_4 AP_{t-7}) + \omega_t \dots\dots\dots\dots\dots\dots (4)$$

All the variables are as earlier defined. Where Δ represents the first difference operator while β3 to β6 are short-run coefficients, λ is the error correction mechanism that measures the speed of adjustment from short-run disequilibria to long-run steady-state equilibrium and ωt is the stochastic error term assumed to be independently and normally distributed with zero mean and constant variance.

Data and Empirical Analysis

Data and Data Sources

The empirical analysis was carried out for three major coconut-producing countries including Sri Lanka, India, and the Philippines with special emphasis on Sri Lanka. The data used for the study consists of annual time series data from 1970-2019, a 50-year span that is capable of capturing the long-run relationships between the variables of interest. Data on Sri Lanka's national-level coconut acreage, production, prices, and average annual rainfall was extracted from the annual publications of the Coconut Development Authority of Sri Lanka. Since it was difficult to compile data at the national level for India, the state of Kerala, the largest coconut producer in India was selected to represent India throughout the analysis. Production and area planted of coconut, prices, and rainfall for the considered period in Kerala were obtained from the https://data.gov.in/data base and Statistical yearbooks of Asia-Pacific Coconut Community (APCC). Data on production and coconut acreage for the Philippines were obtained from the Statistical yearbooks of APCC. Data on average annual rainfall for the Philippines were extracted from the FAO database. All nominal prices were converted to US Dollars using the relevant average exchange rates of the countries in the respective years for the comparison purpose and the prices were deflated by the Consumer Price Index (CPI). Annual average exchange rate and CPI data were obtained from the FAO database. From the preliminary estimation of equation 4, it was found that no cointegrating relationships in the model consist of "area planted seven years earlier (AP). Thus, coconut production (CP) is assumed to be determined by its own price (NPt) and the climate variable, rainfall (RFt)

Empirical Analysis

Unit Root Analysis

As discussed earlier, investigation of the associated time series properties of the individual variables usually precedes VECM estimation. According to Arltová and Darina (2016), the best results for time series with low frequency i.e., T=25-50 can be obtained by ADF and PP test, as is the case of this study, where data from a time span of around 50 years. Therefore, all the individual data series were subjected to ADF, and PP unit root tests are shown in Table 2.

Both tests in both scenarios; with constant and with the constant deterministic trend, reveal that Nut Price (NP) and Rainfall (RF), except for Coconut production (CP), are non-stationary at the level and integrated of order 1, in the case of Sri Lanka. Under the trended test, coconut production is found to be stationary by both tests. All the examined data series in India revealed that all the variables are non-stationary at their level or integrated of order 1 i.e., I (1) according to both ADF and PP test whereas the

Rainfall with the deterministic trend is stationery at the level according to the PP test. Similarly in the Philippines, all the variables, except the Rainfall variable in both tests with and without deterministic trend, are non-stationary or integrated of order 1. Yet, the study proposed to treat the RF variable in the Philippines as I (1) in the analysis that follows. Accordingly, these unit root tests strongly support the null hypothesis that all the variables were not stationary at their level indicating that the variable is I(1) and therefore attempting to postulate any dynamic function of these variables at their level may not be appropriate as it can lead to the spurious regression problem.

In the recent empirical literature, one of the commonly accepted arguments in handling panel data is that the most commonly used unit tests such as ADF and PP test lack power in distinguishing presence of unit root from the stationery alternative, and hence use of panel data unit root tests is one way to increase the power of a unit test (Maddala and Wu, 1999; Jiang and Liu, 2014). Therefore, this study employs Levin-Lin-Chu (LLC) (Levina, *et al.,* 2002), Im, Pesaran, and Shin (IPS), Breitung t-stat, ADF-Fisher Chi-Square, and PP-Fisher Chi-Square tests to test the null hypothesis of non-stationary of panel data. The results of the five panel unit root tests for the three panel variables comprised of three countries; Sri Lanka, India (Kerala), and The Philippines, are summarized in Table 3.

Table 2. ADF and PP unit root test for the variables

Country	Variable	ADF test statistics		Phillips-Perron test statistics	
		Constant without trend	Constant with trend	Constant without trend	Constant with trend
Sri Lanka	Level variable				
	NP	-0.909	-1.265	-2.817 [5]	-5.194 [5]
	RF	-0.589	-2.783	-0.988 [14]	-1.667 [11]
	CP	-1.435	-4.684*	-0.382 [1]	-1.039* [3]
	First difference				
	NP	-12.951**	-12.806**	-13.541**[5]	-13.455**[5]
	RF	-7.278**	-7.174**	-45.269**[44]	-45.494**[44]
	CP	-11.328**	-11.449**	-14.012**[21]	-15.002**[19]
Kerala (India)	Level variable				
	NP	-1.388	-1.238	-1.392[12]	-2.914[0]
	RF	-2.852	-2.998	-0.375[3]	-5.949*[4]
	CP	-0.922(0)	-2.241(0)	-0.799[2]	-2.193[1]
	First difference				
	NP	-8.927**(	-8.974**	-9.611**[18]	-13.630**[23]
	RF	-10.308**(1)	-10.179**(1)	-10.678**[1]	10.541**[1]
	CP	-7.608**(0)	-7.567**(0)	-7.610**[1]	-7.567**[1]
Philippines	Level variable				
	NP	-2.644(0)	-3.376(1)	-2.618[5]	-2.853[6]
	RF	-4.409*(0)	-4.709*(0)	-4.395*[5]	-4.398*[9]
	CP	-1.922(0)	-3.262(0)	-1.897[4]	-3.303[1]
	First difference				
	NP	-5.870**(1)	-5.807**(1)	-8.269**[24]	-8.035**[24]
	RF	-6.824**(2)	-6.734**(2)	-13.115**[20]	-13.157**[19]
	CP	-7.453**(0)	-7.514**(0)	-7.943**[7]	-8.571**[9]

Note: ** and * denotes significance at 1% and 5% significance level respectively. The figures in parenthesis (..) represents the optimum lag lengths selected based on Schwarz Info Criterion. The figures in brackets [..] represent the bandwidth used in the PP test which was selected based on the Newey-West Bandwidth using Bartlett kernel.

Table 3. Results of panel unit root tests

	LLC	Breitung	IPS	ADF-Fisher	PP-Fisher
Level variable					
CP	-0.738	-1.327	0.166	3.971	14.376
NP	-1.630	-1.384	-0.547	8.121	14.264*
RF	-0.656	-6.974**	-8.982*	3.745	4.816
First Difference					
CP	-13.641**	9.105**	-14.311**	111.449**	111.245**
NP	-3.886**	-2.257**	-8.010**	63.801**	126.209**
RF	-9.093**	-7.379**	-12.770**	103.612**	108.441**

Note: ** denotes rejection of the null hypothesis of unit root based on their P-value at the 0.01 significance level.

All unit root tests were individual intercepts for each series except the Breitung test which is the individual intercept and trend of each series. The lag length was determined by the Schwarz Info Criterion. The null hypothesis of IPS, ADF-Fisher, and PP-Fisher tests assume individual unit root processes while LLC and Breitung tests assume a common unit root process. The results of the panel unit root tests represent the fact that all most all the level variables are panel non-stationary, however, all the tests of the first difference reject the null hypothesis at the 0.01significance level. Thus, all the panel series are non-stationary at levels and stationery after the first differencing.

Cointegration Analysis

Since the order of stationary has been defined for both individual and panel data series, it was then followed by cointegration tests to determine if a long-run relationship exists between the coconut production and the selected key factors. This was done by applying the Johansen and Juselius (1992) maximum likelihood approach to identify the number of cointegrating relationships between the variables concerned in the individual countries and the resulting test statistics are reported in Table 4. Based on the Schwarz Info Criterion, the VAR lag length selected for the test is 1 and that is found to be adequate to make the error term serially uncorrelated. The test relations were estimated with intercept and linear deterministic trend for India and the Philippines and with intercept only for Sri Lanka. According to the test results, it is visualized that both the trace and maximum Eigenvalue tests statistics strongly support the hypothesis that there is a unique long run cointegrating relationship among the three variables: CP, NP, and RF, in each country. Thus, in the long run, these variables are tied together, and their paths will be adjusted if they move away from the steady-state equilibrium path of the long run.

Table 4. Results of Johansen's Maximum Likelihood co-integration test

Country	Null Hypothesis	Trace Statistics	Max. Statistics	Critical value (5%)	
				Trace	Max-Eigen
Sri Lanka	r=0	36.6562**	30.9254**	29.68	20.97
	r≤1	5.7307	5.4439	15.41	14.07
	r≤ 2	0.2868	0.2868	3.84	3.84
Kerala (India)	r=0	58.3441**	43.3427**		
	r≤1	15.0015	14.2503		
	r≤ 2	3.5447	3.5447		
Philippines	r=0	53.250**	37.909**		
	r≤1	15.340	12.091		
	r≤ 2	3.250	3.250		

Note: ** denotes significance at 5% critical level.

As a dynamic panel consists of large cross-section dimensions, Johansen and Juselius' (1992) framework is not likely to be realistic, and hence use of a panel cointegration method is more appropriate when dealing with panel data (Jiang and Liu, 2014). Hence, this study employed Pedroni's test, a heterogeneous panel cointegration test, to allow the existence of cross-sectional interdependencies within different individual effects (Pedroni, 2001), the residual-based panel cointegration test proposed by Kao (1999) and the Johansen Fisher panel cointegration test developed by Maddala and Wu (1999) based on the trace and maximum eigenvalue test statistics. The results of the three panel cointegration tests are presented in Table 5.

The Pedroni panel cointegration test includes seven different test statistics, where four of them are based on pooling the residuals of the regression within the dimension of the panel and the rest of the three are based on pooling the residuals between the dimension of the panel. The results of the Pedroni test presented in Table 5 reveal that the null hypothesis of no cointegrating for all tests at 1% and 5% significance level except the group v-statistic which the null can be rejected at 10% significance level. Moreover, Kao test statistics also support the rejection of null at 5% significance level. Johansen-Fisher test statistics support the presence of a cointegrating relationship, and it further reveals that there is only one cointegrating equation exists between the variables of interest. Hence, it can be concluded that this model is in fact panel cointegrated.

Table 5. Results of the panel cointegration tests

Pedroni Cointegration tests (CP as the dependent variable) - Test statistics			
Within dimension		Between dimension	
Panel v-statistic	1.5087 *	Group rho-statistic	-1.6976**
Panel rho-statistic	-2.0074**	Group PP-statistic	-3.0865***
Panel PP-statistic	-2.3456***	Group ADF-statistic	-3.5650***
Panel ADF-statistic	-2.3297***		
Kao test ((CP as the dependent variable)			
ADF	-2.2917**		
Johansen-Fisher panel cointegration test- Fisher statistic			
	from trace test	from max-eigen test	
None	18.73***(0.0046)	13.70***(0.0332)	
At most 1	10.37(0.1100)	9.09(0.1689)	
At most 2	10.73 (0.0970)	10.73(0.0970)	

Note: ***, ** and * represent significance at 1%, 5% and 10% significant level, respectively. The optimal lag length was selected based on the Schwarz Info Criterion and it suggests an optimal lag length of 2.

According to Johansen's Maximum Likelihood test and three panel cointegration tests conducted, there is strong statistical evidence in favor of cointegration in both scenarios; individual three countries and balanced panel, and presence of one cointegration equation.

VECM Estimation

Once the existence of co-integration among the dependent variable is identified then a VECM can be established to estimate the short-run and long-run relationships among the variables concerned. Nevertheless, where there a single co-integrating equation exists, its parameters can be interpreted as estimates of the long run cointegrating relationship between the variables concerned (Hallam and Zanoli, 1993). Therefore, this cointegrating vector was normalized with respect to coconut production (CP) and can be interpreted as the long-run coconut supply response function. Table 6 shows the results of the VECM estimates for the supply response of individual countries and the panel data including both short-run and long-run estimates and diagnostic tests. For the comparison purpose of these estimates, they are presented in Figure 1 as well.

Table 6. VECM estimates of individual countries and panel data

	Sri Lanka	India	Philippines	Panel Estimation
ECT1	-0.134*	-0.112*	-0.08*	-0.140**
Long-run estimates (normalized on CP $_t$)				
Constant	-2.281	-2.620	2.330	-11.523
NP_t	0.064*	0.288**	0.106**	-0.018
RF_t	1.936**	-0.970*	-1.616*	0.566**
Trend				-0.018**
Short-run estimates				
$D(CP)_{t-1}$	-0.129	-0.154	-0.004	-0.172**
$D(CP)_{t-2}$	-0.399**	-0.130	-0.142	-0.324**
$D\ (NP)_{t-1}$	0.068	0.016	0.030*	0.025*
$D\ (NP)_{t-2}$	0.069*	0.136**	-0.014	0.027
$D(RF)_{t-1}$	0.370**	0.089	-0.015	0.174**
$D\ (RF)_{t-2}$	0.214*	-0.037	0.129*	0.018**
Diagnostic tests				
R2	0.58	0.43	0.22	0.416
JB	3.392 (0.758)	1.676(0.433)	2.058(0.357)	10.430(0.107)
LM test (2)	10.590 (0.304)	8.573(0.478)	10.829(0.288)	26.558(0.030)

Note: ** and * represent significance at 1% and 5% significant levels, respectively. Figures in parenthesis (...) are p values.

The estimated coefficients of the one-lagged Error Correction Term (ECT t-1) which captures the production adjustment towards the long-run equilibrium (speed of adjustment) has the priori expected negative sign and it is significant in all four scenarios. In Sri Lanka, the estimated coefficient of -0.134 suggests that the previous year's production disequilibrium is corrected by 13.4% each year. The estimated adjustment coefficient of -0.112 implies that only about 11.2% of the deviation of the coconut production from the long-run equilibrium level is corrected per year. Adjustment of coconut production in the Philippines is somewhat lower than that of the other two countries and the coefficient of -0.08 suggests that only 8% of the previous year's disequilibrium is corrected per year. The resulting ECT for the panel estimation is -0.14 and it proposes that 14% of the deviation of coconut production from the long-run equilibrium is corrected per year. Therefore, it will take approximately 7.14 years to adjust to the long-run equilibrium. As stated by Child, (1974) and Silva, (1979), majority of the coconut plantation consists of tall varieties of which a palm has a four to seven years gestation period from the year of planting to the initial bearing except in the case of improved hybrid varieties which have been introduced in the recent past. Therefore, in the long run, where the productive capacity is changing, a change in the current investment decision on production would be thrived in profitability seven years later due to lagged response of new plantings and replanting.

The results revealed that the magnitudes and signs of long-run coefficients are reasonable and consistent with the prior expectation. In Sri Lanka, a positive and significant long-run association between CPt and NPt, was observed. Furthermore, the long-run elasticity of coconut production with respect to nut price, is inelastic (0.064), implying that in the long run, Sri Lankan coconut growers can make only small adjustments to coconut production in response to changes in the prices. Long-run estimates of NPt in India and the Philippines show positive signs with varying magnitudes. Accordingly, the responsiveness of Indian and Philippine coconut producers to change in their own price is 0.288 and 0. 106 respectively. These long-run own price elasticity estimates are consistent with the long-run supply elasticity values obtained for other perennial crops, including rubber, 0.18 (Alias, *et al.*, 2001) and 0.204 (Mesike, *et al.*, 2010), peaches, 0.13 (aajimi, *et al.*, 2008), apple, 0.33 and pears 0.28 (Wani, *et al.*, 2015) by employing an empirical approach similar to this study. However, in the panel estimation, the coefficient of fresh nut price is not significant in the long run. RF is positive and significantly contributes to the CP in the long run except in the estimation of India and the Philippines as they exhibit a negative and significant relationship.

The short-run elasticities represented by the coefficients of the lagged variables are consistent with the theoretical expectation in terms of both sign and magnitude. The short-run own-piece elasticity of coconut production is positive and significant. In Sri Lanka and India, only the two years lagged nut price is significant and the elasticity values are 0.069 and 0.136 respectively. In contrast, the one-year lagged short-run own price elasticity in the Philippines is 0.03, suggesting the presence of a comparatively efficient price information dissemination mechanism to the producers. A lag distinction can be observed within countries and across countries in the short rub estimates as shown in Figure 1. The responsiveness of coconut production to both one-year and two-year lags of rainfall in Sri Lanka is positive and significant and they are 0.37 and 0.214 respectively.

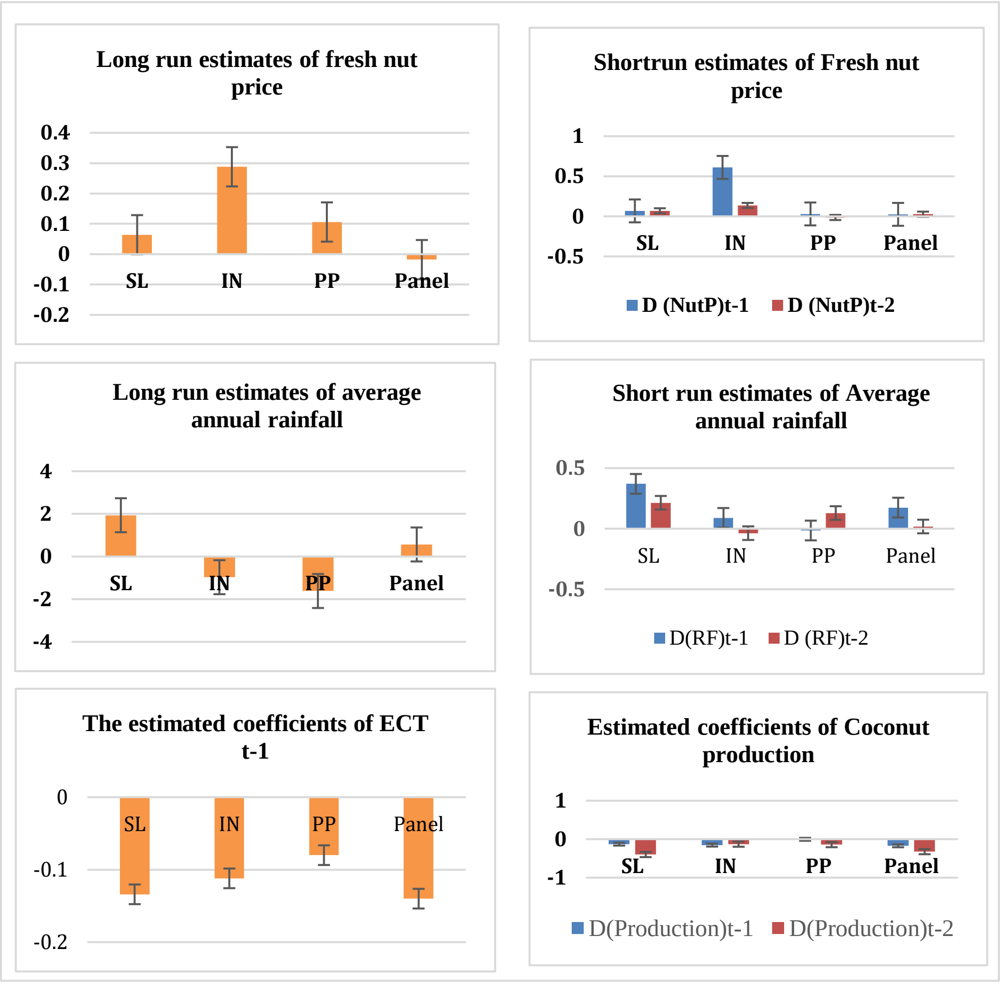

Figure 1. Long-run and short-run estimates and estimates of ECT based VECM

In the Philippines, two-year lag rainfall positively influences coconut production. This phenomenon can be observed in the panel estimation as well. These findings are consistent with the theoretical evidence conveyed by Child, (1974) and Peries and Peries, (1993), by proposing 1–2 year lag of rainfall influences the fresh nut production. In India, the short-run supply elasticity of coconut with respect to rainfall is not significant. However, according to Karunakaran and Gangadharan, (2014) who study the coconut cultivation Kerala alike to this study, the irrigated area is one of the most influencing determinants of coconut yield in Kerala. However, due to limitations in data availability, the variable of the irrigated area is not accounted for in the present study. Both one and two years lagged coconut production is negative in all four estimations where it is significant only in the panel estimation. In terms of the model adequacy, according to the diagnostic tests the equations have statistically quite sufficiently performed in explaining the coconut supply response. In particular, the null hypothesis of no autocorrelation in the residuals was not rejected in the LM test of autocorrelation.

According to Baltagi, (2005), a panel data analysis with a richer regional data set would provide more variability allowing heterogeneity between regions and thus less collinearity among variables. Further, since there are more degrees of freedom, estimated parameters will be more efficient in panel estimation. However, due to constraints in obtaining data for more variables to generate a balanced panel, a simple model has to be used in the study with limited variables. Moreover, this study was unable to find a long-run relationship between the coconut production and the replanting acreage represent by the share of total coconut acreage may be due to poor quality of data and/ or due to poor size and power properties in the conventional cointegrating tests, when the sample is of moderate length (Juselius, cited in Soontaranurak and Dawson, 2015) as in this study. Further, this methodology could be extended to estimate the acreage response, an alternative approach widely used, as well. More importantly, the empirical approach employed in this study addresses the limitations of restrictive lag structure and spurious regression which is common to the widely used Nerlovian models estimated using classical regression.

Conclusions and Policy Implications

The supply responsiveness of perennial crops has received greater attention in the recent theoretical and empirical literature due to its role in assessing the behaviour of the producers in response to the changes in both price and non-price determinants. This paper contributes to this line of interest by assessing the long-run and short-run relationships among coconut production, producer price of fresh nuts, and rainfall in three producer countries and a balanced panel comprises of these three countries, from 1970 through 2019, by employing an empirical approach organizes within the VECM framework.

Results show that a unique long-run equilibrium exists between coconut production and its determinants namely own price and rainfall in the three individual producer countries and the panel estimation as well. The long-run own price elasticity in Sri Lanka, India (Kerala), and Philipinnes are 0.064, 0.288, and 0.106 implying that the coconut price is inelastic in the long run. Similarly, the lagged price is found to be significantly and positively affect coconut production in the short run. Nevertheless, lower magnitudes of corresponding short-run price elasticities suggest that the own price is inelastic in the short run as well. In terms of the responsiveness of coconut production to rainfall, show mixed results indicating that supplementary irrigation is one of the major determinants even though coconut is widely considered as a rainfed crop. However, the regional variations or disparities are revealed by the short-run dynamics throughout. The speed of adjustment towards long-run equilibrium has the expected sign and it is significant in all four estimations with a -0.14 value in the panel estimation. Thus, 14% of adjustment is completed each year and it will take nearly 7.14 years to achieve the long-run equilibrium. This is quite an optimal adjustment considering the biological nature of the crop with a gestation period of 5-7 years which can create an extended phase of disequilibrium in the planned supply. The panel estimation supports the findings arising from the individual country estimation.

The econometric estimates of the coconut supply responses in this study provide strong evidence that the coconut producers respond rationally to the changes in own price and other supply determinants. Hence, pricing policies are effective tools in influencing and achieving the desired production. However, both short-run and long-run price elasticities of coconut supply response function are rather low amidst its significance, suggest that any pricing policy requires a comparatively long lead time for it to become effective in accelerating the coconut production in the producing countries considered. Furthermore, the panel VECM model employed in this study can be further developed and validated to be used as a tool to analyze the regional deviances for assisting the policymakers in making comprehensive strategies to ensure the long-term sustainability of the global coconut industry.

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ISSN 1391-7358