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Analysis of the Interrelationships between the Prices of Sri Lankan Rubber, Tea and Coconut Production Using Multivariate Time Series

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Abstract With the globalization of the economy and the financial markets today, price movement of one market can spread easily and instantly to another market. Because of these financial markets are more or less dependent on each other, there is a need to study their interrelationships to understand the dynamic structure of the financial economy. In this paper, we use Vector Auto Regression (VAR) Analysis to study the interdependency of the price of tea, rubber and coconut production in Sri Lanka. We also measured the strength of the linear interrelationship between the assets using the $lag-l$ cross-correlation matrix (CCM) and also fit a VAR-model using selection criteria based on the AIC, SIC and HQIC. We examined the individual behaviour of the separate prices of each asset and then analysed the combined effects of the prices. Out of all computing models, we observed that tea price was ARIMA (0,1,0), rubber price was ARIMA (3, 1, 1) and coconut price is ARIMA (0, 1, 3). Thus they were all integrated of order I(1). We investigate if there is a cointegration between the assets to see if there was a long-run equilibrium, and there was at most one cointgretion equation. Hence we used the Vector Error Correction model (VECM), for the estimation. We observed that coefficients between any of the variables were not equal to zero. The coefficient estimates between tea and rubber were not the same as between rubber and tea at all lags, between tea and coconut, as well as between rubber and coconut. Which indicate that there may be feedback relationship between all the three series. Further, impulse response analyses were used to observe the impacts. There was a fairly strong correlation between them, hence it could be concluded that, there is a linear dependency of all the variables.

Keywords Cross-correlation Matrix, Cointegration, Vector Error Correction

1. Introduction

Agricultural sector plays very important role in Sri Lankan economy. From 2010-2012, it has approximately employed 31.3% annually for the labour force. The sector has also contributed approximate annual income of Rs 1307698 million from 2000-2012 as a support to the GDP of Sri Lanka (Department of Census and Statistics, 2013)[7]. Tea, rubber and coconut are some of the major agricultural commodities that contribute immensely to the GDP of Sri Lanka. They also serve as a key employment area for the economy.

Tea production in Sri Lanka is of high importance to the Sri Lankan economy and the world market. Sri Lanka is the fourth largest tea producer in the world. The tea industry is one of the country's main sources of foreign exchange and a significant source for employment. Tea is accounting for 12% of the GDP and generated roughly on the average of Rs 77212.33 million annually from 2011–2013. The tea sector currently employs directly or indirectly over one million people in Sri Lanka and in 1995 directly employed 215,338 on tea plantations and estates. Annual Report (2010–2011) [6,13].

In the world, Sri Lanka is one of the nine major producers of natural rubber, and in terms of productivity, is now the third best following India and Indonesia. From 2011-2013, rubber has contributed on the average of Rs 46040 million per year to the GDP of Sri Lanka. The rubber sector employs directly or indirectly over one million people in Sri Lanka.

Coconut is one of the common food product found in Sri Lanka. From 2011-2013, coconut has contributed on the average Rs 71876.33 million per year to the GDP of Sri Lanka. The coconut estates employ directly or indirectly over one million people in Sri Lanka as well. (Department of Census and Statistics, 2013)

Various researchers have looked at different estimations of the returns on the individual crops, but we believe that with the globalization of the economy and the financial markets today, price movement of one market can spread easily and instantly to another market. Since these financial markets are more or less dependent on each other, there is a need to study their interrelationships to understand the dynamic structure of the financial economy. In this paper we use Vector Auto Regression (VAR) Analysis to study the interdependency of the returns on tea, rubber and coconut which are some of the important cash crops in Sri Lanka.

The objective of the study is to understand the dynamic structure of the financial economy. In order to achieve this objective, in particular, the study would explore the following specific objectives, to examine behaviour of the prices of the individual assets, to investigate the interrelationship between the prices of tea, rubber and coconut and the total behaviour of the effects of the prices on the assets.

The study will establish, if the price movement of one market can spread easily and instantly to another market which makes financial markets more or less dependent on each other, hence the need to study their interrelationships to understand the dynamic structure of the financial economy. This study is also done to add knowledge to the understanding of the interrelationship between these important plantation crops and their returns on the GDP of the Sri Lankan economy.

Hypothesis:

H0: There is interrelationship between the prices of tea, rubber and coconut

H1: There is no interrelationship between the prices of tea, rubber and coconut

2. Materials and Methods

Data Source

Annual secondary data was collected from FAOSTAT [9], food balance sheet, price statistics and from, Department of Census and Statistic Sri Lanka. These data comprises of the annual prices of tea, rubber and coconut from 1966 - 2009. The estimates in real terms of the past data series were based on the constant prices of 1958, 1963, 1975 and 1990. The current price estimates were at current factor cost prices until 1975 and thereafter it was at current producer prices. The National Accounts estimates are compiled based on the UN - guidelines given in the System of National Accounts (SNA), Ministry Of Statistics (2010)[11].

Statistical Software

The R software was used in analysing and fitting the VECM models.

Behaviour of the Data

Figure 1 is the time series plot showing the behaviour of the price of the variables tea, rubber and coconut between 1966-2009, with prices of rubber having a higher upward growth/movement than the others. Tea and rubber prices exhibit similar characteristics. Initially there was an increase in growth of tea prices from 1966-1998, however, there were sharp drops in 1999 and 2000.

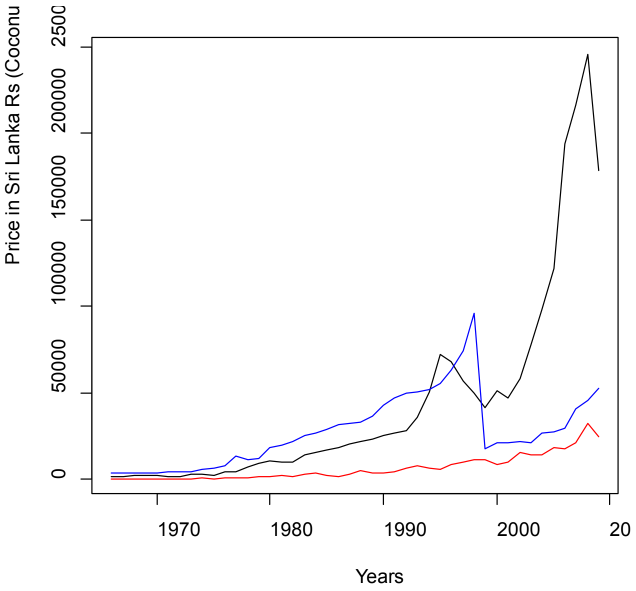

Figure 1. Time series plot of the price of tea (blue colour), rubber (black colour) and coconut (red colour) in the period (1966-2009)

2. Methodology

Let $X_1,\ X_2\ and\ X_3$ be the individual price of the assets tea, rubber and coconut respectively, and X_t the total returns with $X_t = (X_{1t}, X_{2t}, X_{3t})'$ of the assets at time *t,* where a' denotes the transpose of a. Then let a stochastic process $\{x_{it} : t \in Z\}$ be an autoregressive process of order p(≥ 1) (AR(P)-process),

$$X_{1t} = \sum_{k=1}^{p} \alpha_k x_{t-k} + \varepsilon_t, \quad -1 < t < \infty, \quad \alpha_p \neq 0$$

$$x_{2t} = \sum_{k=1}^{p} \alpha_k x_{t-k} + \varepsilon_t, \quad -1 < t < \infty, \quad \alpha_p \neq 0$$

$$x_{3t} = \sum_{k=1}^{p} \alpha_k x_{t-k} + \varepsilon_t, \quad -1 < t < \infty, \quad \alpha_p \neq 0$$

where $\{\varepsilon_t\}$ is a white noise.

Richard and Johnson (2012) [12] and Anderson (1951, 1984) [3,4] define the mean vector and the covariance matrix as:

$\mu = E(X_t)$ is the k-dimensional vector of the unconditional expectations of X_t and

$$\Gamma_0 = E[X_t - \mu][X_t - \mu]'$$

where Γ_0 is a $k \times$k matrix and $\mu = (\mu_1, \cdots, \mu_k)'$ and the $(i,j)^{th}$element of Γ_0 is the covariance of $X_{it}\ and\ X_{jt}$.

Let D be a $k \times$k matrix diagonal matrix consisting of the standard deviations of X_{it} for $i = 1, \cdots, k$.

Then $D = diag[\sqrt{\Gamma_{11}(0)}, \cdots \sqrt{\Gamma_{kk}(0)}$

The *lag-zero cross-correlation matrix* (CCM) of X_t is given by

$$\rho_0 = [\rho_{ij}(0)] = D^{-1}\Gamma_0 D^{-1}$$

where
$\rho_{ij}(0) = \rho_{ji}(0)$ and $-1 \leq \rho_{ij}(0) \leq 1$ and $\rho_{ii}(0) = 1$
for $1 \leq i, j \leq k$.

Thus $\rho(0)$ is a symmetric diagonal matrix with unit elements. This is used to measure the strength of the linear dependence between the time series variables.

The $\boldsymbol{Lag - l}$ **cross-covariance** matrix of X_t is given by

$$\Gamma_l = [\,\Gamma_{ij}(l)] = E([X_t - \mu][X_{t-l} - \mu]')$$

where the $(i,j)^{th}$ element of Γ_l is the covariance of X_{it} and $X_{j,t-l}$.

And the $lag - l$ cross-correlation matrix of X_t is defined as
$\rho_l = [\rho_{ij}(l)] = D^{-1}\Gamma_l D^{-1}$ the cross covariance matrix can be estimated.

Given a time series X_t, The Vector Autoregressive (VAR) model of order 1 or VAR(1) is defined as:

$$X_t = \phi_0 + \Phi X_{t-1} + a_t$$

where ϕ_0 Is a k-dimensional vector, Φ is a $k \times k$ matrix and $\{a_t\}$ is a sequence of serially uncorrelated random vectors with mean zero and covariance matrix Σ, which is required to be positive definite. Ang. et al (2003),[1]. Therefore, for a VAR(1) with

$$k = 3, \qquad X_t = (X_{1t}, X_{2t}, X_{3t})' \; and \; a_t = (a_{1t}, a_{2t}, a_{3t})'$$

Hence, we have the following equations:

$$X_{1t} = \phi_{10} + \Phi_{11}X_{1,t-1} + \Phi_{12}X_{2,t-1} + \Phi_{13}X_{3,t-1} + a_{1t}$$

$$X_{2t} = \phi_{20} + \Phi_{21}X_{1,t-1} + \Phi_{22}X_{2,t-1} + \Phi_{23}X_{3,t-1} + a_{2t}$$

$$X_{3t} = \phi_{30} + \Phi_{31}X_{1,t-1} + \Phi_{32}X_{2,t-1} + \Phi_{33}X_{3,t-1} + a_{3t}$$

Where Φ_{ij} is the $(i,j)^{th}$ element of Φ and ϕ_{i0} is the i^{th} element of ϕ_0.

The Error Correction Model

Cointegration is a relationship between two nonstationary, I(1), variables (Reinsel, 1990)[2]. These variables share a common trend and tend to move together in the long-run. A dynamic relationship between I(0) variables which embeds a cointegrating relationship known as the short-run error correction model.

Consider a k-dimensional VAR(p) time series X_t then;

$$X_t = \phi_0 + \Phi_1 X_{t-1} + - - - + \Phi_p X_{t-p} + a_t$$

Then an error correction model (ECM) for the VAR(p) is given by

$$\Delta X_t = \phi_0 + \pi X_{t-1} + \Phi_1^* \Delta X_{t-1} + \cdots + \Phi_{p-1}^* \Delta X_{t-p+1} + a_t$$

where

$$\pi = \alpha\beta' = \Phi_p + \Phi_{p-1} + \cdots + \Phi_1 - I = -\Phi \qquad (1)$$

Determination of the Lag Length

The optimum lag length was selected based on the selection procedure proposed by Akaike Information Criterion (AIC), Schwarz Information Criterion (SIC) and Quinn Information Criterion (HQIC).

3. Results and Discussion

Descriptive statistic of prices of tea, rubber and coconut (in Rupees) between 1966–2009 is given in Table 1.

Table 1. Descriptive statistical of return on tea, rubber and coconut (in Rupees)

Variable	Obs	Mean	Std. Dev	Q1	Min	Q3	Max
Tea Price	44	27645	21219	8730	3300	42424	96170
Rubber Price	44	44353	60100	4383	1740	55378	245750
Coconut Price	44	6437	7480	670	180	9944	32354

From Table 1, it can be seen that the average price of tea between 1966-2009 was Rs 27645 per tonne with a minimum price of Rs 3300 and maximum of Rs 96170 per tonne. Also it could be observed that the average price of rubber between 1966-2009 was Rs 44353 per tonne with a minimum price of Rs 1740 and maximum of Rs 245750 per tonne. An average coconut price was Rs 6437 per tonne, with a minimum price of Rs 180 per tonne and a maximum price of Rs 32354 per tonne.

Dickey Fuller Unit-root Test

In order to establish the order of the series, the Augmented Dickey Fuller unit-root test was used to investigate whether the series of the prices of tea, rubber and coconut were stationary. Results are given in Table 2.

Table 2. Dickey-Fuller test for unit root results

Variable	Test statistic	1% critical value	5% critical value	10% critical value	p-value
Tea	-2.072	-3.628	-2.950	-2.608	0.2559
Rubber	0.268	-3.628	-2.950	-2.608	0.9758
Coconut	-0.024	-3.628	-2.950	-2.608	0.9565

Considering the results from Table 2, since p-value (P>0.05) at all the critical values, we fail to reject the null hypothesis that there is unit root at all the critical values (1%, 5%, and 10%) for all the variables.

Model Selection for the Individual Assets

Using Akaike Information Criterion and Schwarz Information Criterion as selection criteria for the individual asset model is summarized below:

Model for Tea Price

ARIMA(0,1,0)

AIC=938.54 AICc=938.64 BIC=940.3 log likelihood = -468.27

The best model based on the selection criteria for tea price was ARIMA (0, 1, 0).

Model for rubber price is given in Table 3.

Table 3. Model for rubber price

ARIMA (3, 1, 1)	Constant	ar1	ar2	ar3	ma1
Coefficients	3327.862	0.454	0.4588	-0.7935	0.0005
Standard Error	2379.602	0.223	0.1379	0.1364	0.2757

AIC=952.6 , AICc=954.93 , BIC=963.16 , log likelihood=-470.3

From Table 3, the best model for the rubber price is ARIMA (3, 1, 1) based on the selection criteria.

Model for coconut price is given in Table 4.

Table 4. Model for coconut price returns

ARIMA (0, 1, 3)	Constant	ma1	ma2	ma3
Coefficients	680.972	-0.3992	-0.2711	0.7898
Standard Error	332.6319	0.1060	0.2480	0.211

AIC=789.06, AICc=790.68, BIC=797.86, log likelihood = -389.53

From Table 4, the best model for the coconut price is ARIMA (0, 1, 3) based on the selection criteria.

Johansen tests for cointegration

We investigate, whether tea, rubber and coconut prices have a long-run equilibrium by performing a cointegration test (Johansen, 1988) [10]. Johansen tests results for cointegration are given in Table 5.

Table 5. Johansen tests for cointegration

Maximum rank	Parms	LL	Eigenvalue	Trace statistics	5% critical value
0	12	-1303.5		36.8114	29.68
1	17	-1288.8	0.50493	7.2828*	15.41
2	20	-1285.8	0.13325	1.2767	3.76
3	21	-1285.2	0.02994		

We observe in Table 5 that, at Rank (0) the Trace statistic is 36.8 which is greater than 29.68; hence we reject the hypothesis at 5% critical value that there is no cointegration between tea, rubber and coconut. That is there is a long run association. But at all the other Ranks, the Trace values were less than the 5% critical values. Therefore, we used the Vector Error Correction model (VECM) (Granger et al., 1987) [8].

Multivariate Analysis for the VECM- Model

Lag selection order

Using the lag selection procedure for the maximum lags for the VECM-model, we used the AIC, HQIC, and SBIC selection criteria. The summary is given in Table 6.

With tea, rubber and coconut prices as endogenous and the constant as exogenous factors, using the lag selection criteria of AIC, HQIC and SBIC, a maximum of optimal seven lags (7) were selected for the VEC-model as shown on Table 6.

Vector Error Correction model (VECM)

Table 7 is showing the summary of the optimum model selection for the VECM - Model based on the selection criteria AIC, SBIC, and HQIC, respectively.

AIC = 56.26621, SBIC = 58.96558, HQIC = 57.21786, Log likelihood = -978.924

Table 6. Lag selection using AIC, HQIC and SBIC

Lag	LL	LR	df	P	FPE	AIC	HQIC	SBIC
0	-1221.49				1e+25	66.1886	66.2346	66.3192
1	-1151.29	140.4	9	0.000	4.1e+23	62.8805	63.0647	63.4029
2	-1138.18	26.211	9	0.002	3.3e+23	62.6586	62.9809	63.5729
3	-1115.62	45.131	9	0.000	1.6e+23	61.9253	62.3858	63.2315
4	-1062.35	106.54	9	0.000	1.6e+22	59.5324	60.1311	61.2304
5	-1028.42	67.856	9	0.000	4.5e+21	58.185	58.9217	60.2748
6	-1001.78	53.278	9	0.000	2.0e+21	57.2315	58.1064	59.7132
7	-972.574	58.419	9	0.000	8.3e+20	56.1391	57.1522	59.0126

Table 7. VECM -model Selection

Equation	Parms	RMSE	R-sq	chi2	P>chi2
D_Tea	20	6228.82	0.9089	169.6666	0.0000
D_Rubber	20	5481.39	0.9628	439.7099	0.0000
D_Coconut	20	924.029	0.9526	341.4395	0.0000

From Table 7 with root mean square error (RMSE) of 6228.82, 5481.39 and 924.03 for tea, rubber and coconut and R-square of 0.91, 0.96 and 0.95 for tea, rubber and coconut, respectively. The selected model approximately explains about 93% of the variation of the data.

Analysis of the equations

Tea parameter estimates

The summary of the parameter estimation for tea as the dependent variable is given in Table 8.

Table 8. Estimated coefficients for tea prices as dependent variable

Variables – D_Tea	Coef.	Std. Err.	z	P>|z|
Tea				
L3D	.5559323	.2282418	2.44	0.015
L4D	.924374	.3188231	2.90	0.004
L6D	.6988486	.3490157	2.00	0.045
Rubber				
L2 D	1.191664	4140998	2.88	0.004
L3D	2.196163	.6037656	3.64	0.000
L6D	-2.044941	.9123783	-2.24	0.025

In Table 8, the error correction term was not significant hence there is no long run causality between tea, rubber and coconut. Tea depends on it lags 3,4 and 6 difference and on lags 2,3, and 6 differenced of rubber, hence there is a short run causality between tea and rubber but not coconut.

Coconut parameter estimates

The summary of the parameter estimation for coconut prices as the dependent variable is given in Table 9.

From Table 9, the error correction term is significant; hence there is long run causality between rubber, tea and coconut. Coconut depends on tea at lag 1, rubber at lags 2 and 5 and coconut at lags 1 and 2 difference, respectively. Hence there is short run causality between rubber, tea and coconut.

Table 9. Estimated coefficients for coconut prices as the dependent variable

Variables – D_Coconut	Coef.	Std. Err.	z	P>|z|
L1	1.248619	.6313494	1.98	0.048
Tea				
LD	.1103913	.0471179	2.34	0.019
Rubber				
L2D	.1759813	.0614307	2.86	0.004
L5D	.3823159	.1393782	2.74	0.006
Coconut				
LD	-1.810611	.6487472	-2.79	0.005
L2D	-2.086044	.6913349	-3.02	0.003

Rubber parameter estimates

The summary of the parameter estimation for rubber prices as the dependent variable is given in Table 10.

Table 10. Estimated coefficients for rubber prices as the dependent variable

Variables –D_Rubber	Coef.	Std. Err.	z	P>|z|
L1	26.74918	3.745197	7.14	0.000
Tea				
LD	.5514238	.2795056	1.97	0.049
L2D	.6602082	.2713432	2.43	0.015
L3D	.9596806	.2008539	4.78	0.000
L4D	1.061325	.2805658	3.78	0.000
L5D	1.30957	.2111087	6.20	0.000
L6D	.9580264	.3071354	3.12	0.002
Rubber				
LD	2.681794	.4209982	6.37	0.000
L2D	3.333131	.3644098	9.15	0.000
L3D	1.822291	.5313165	3.43	0.001
L4D	1.672864	.5021341	3.33	0.001
Coconut				
LD	-25.48814	3.848401	-6.62	0.000
L2D	-21.77069	4.101034	-5.31	0.000
L3D	-17.72586	3.393377	-5.22	0.000
L4D	-14.8394	3.247015	-4.57	0.000
L5D	-8.10452	2.134342	-3.80	0.000
L6D	-5.199878	2.312453	-2.25	0.025

From Table 10 above, the error correction term is significant; indicating the existence of long run causality between rubber, coconut and tea. Rubber depends on tea at all the six lags, Rubber at lags 1, 2, 3 and 4 and Coconut at lags 1 and 2, 3, 4, 5, and 6 differences respectively. Hence there is short run causality between rubber, tea and coconut.

Diagnostic Test

Autocorrelation Test

Using the Lagrange-multiplier test, we tested for autocorrelation at lags 1 and 2. Table 11 shows the summary of results:

Table 11. Lagrange-multiplier test for autocorrelation

Lag	chi2	df	Prob > chi2
1	12.8672	9	0.16871
2	9.7464	9	0.37140

From Table 11, with probability of 0.0168 and 0.0371 for lags 1 and 2, respectively. This indicates that there is no significant autocorrelation at the lag order.

Normality Test

Using Jarque-Bera, we tested for normality in the residuals. Results of Jarque-Bera normality test for the residuals is given in Table 12,

Table 12. Jarque-Bera normality test for the residuals:

Equation	chi2	df	Prob > chi2
D_tea	0.393	2	0.82166
D_rubber	0.869	2	0.64746
D_coconut	0.386	2	0.82443
ALL	1.648	6	0.94904

From Table 12, we observed that all the probability values of the variables including the overall have P>0.05, hence the residuals are normally distributed.

Correlation Matrix

As proposed by Moynihan (1990) [5], the cross-correlation matrix of the variables is summarized in Table 13.

Table 13. Correlation matrix

Variable	Coconut	Rubber	tea
Coconut	1.0000	0.9395	0.4674
Rubber	0.9395	1.0000	0.4241
tea	0.4674	0.4241	1.0000

From Table 13, the correlation between rubber and coconut is 0.94. There is an indication of strong positive relationship between the prices of rubber and coconut.

The correlation between coconut and tea prices is 0.47 which is fairly strong. And the correlation between rubber and tea prices is 0.42 which is also fairly strong.

Impulse Responses (IR's)

The Impulse Response (IR's) is given in Figure 2. The first row shows rubber responses from the shocks of rubber price, coconut price and finally tea prices. The second row shows rubber responses to the shocks of rubber price, coconut price and finally tea prices. The third row shows rubber responses from the shocks of rubber price, coconut price and finally tea prices.

4. Conclusions

There is also both long run and short run causality among tea, rubber and coconut prices. The coefficient estimates between tea and rubber are not the same as between rubber and tea at all lags, between tea and coconut, as well as between rubber and coconut. This indicates that there is a feedback relationship between the three series.

From the analysis above it could be observed that the coefficients between any of the variables was not equal to zero, that is, there is an indication of linear dependency of all the variables. We could conclude that the price movement of one market can spread easily and instantly to another market and also there is a fairly strong correlation between the prices of the assets. Therefore, financial markets are more or less dependent on each other; hence there is an interrelationship between variables which can explain the dynamic structure of the financial economy.

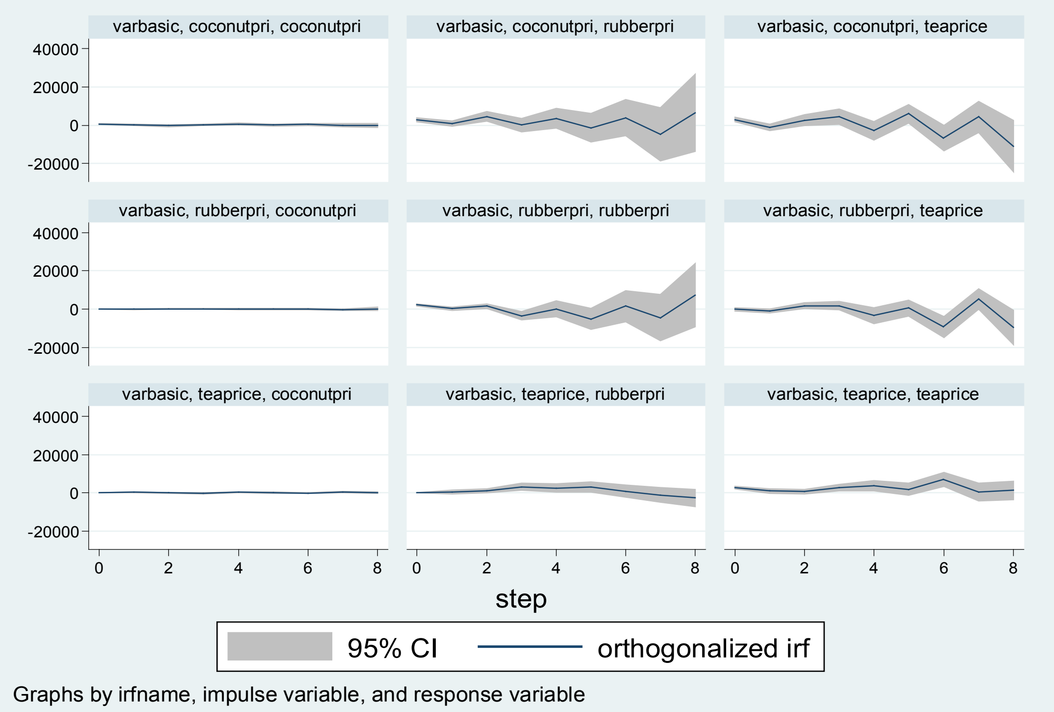

Figure 2. Impulse response (IR's) of rubber, coconut and tea.

Appendix

Attached is the time series data of annual prices of tea, rubber and coconut from 1966 - 2009.

years	coconut	rubber	tea
1966	180	1740	3470
1967	235	1740	3300
1968	300	1940	3850
1969	310	2290	3370
1970	315	2000	3600
1971	290	1740	3990
1972	260	1780	4170
1973	385	2570	4160
1974	500	2820	5850
1975	420	2490	6120
1976	570	4340	7790
1977	1010	4510	13150
1978	970	6920	11550
1979	1170	9150	12190
1980	1660	10620	18330
1981	1930	10040	20000
1982	1750	10180	22000
1983	2540	13950	25000
1984	3870	15340	27000
1985	2240	16800	29000
1986	1592	18560	31320
1987	2855	20420	32465
1988	4737	21900	33300
1989	3552	23500	36840
1990	3419	25100	42945
1991	4513	26800	46680
1992	6194	28262	49660
1993	7773	35660	50410
1994	6213	50340	51945
1995	5467	72450	55070
1996	8333	67880	62865
1997	9573	56710	73990
1998	11013	49830	96170
1999	11547	41650	17940
2000	8347	51380	21090
2001	10067	46790	21050
2002	15773	58440	21830
2003	14387	77880	21079
2004	13856	98370	26430
2005	18065	122160	27180
2006	17253	193720	29190
2007	21154	216670	40860
2008	32354	245750	45450
2009	24306	178370	52710

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