TIME SERIES ANALYSIS AND FORECASTING OF THE PRICES OF INDIAN NATURAL RUBBER

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DECLARATION

I, hereby declare that the thesis entitled **"Time series analysis forecasting of the prices of Indian Natural Rubber"** is a bonafide record of research work done by me during the course of research and the thesis has not previously formed during the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

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LIST OF ABBREVIATIONS

ACF	-	Autocorrelation function
ADF	-	Augumented Dickey Fuller
AIC	-	Akaike Information Criterion
ARIMA	-	Autoregressive Integrated Moving Average
BIC	-	Bayesian Information Criterion
CV	-	Coefficient of Variation
DW	-	Durbin-Watson
GARCH	-	Generalized Autoregressive Conditional Heteroscedasticity
KLCE	-	Kuala Lumpur Commodity Exchange
NR	-	Natural Rubber
OLS	-	Ordinary Least Square
PACF	-	Partial autocorrelation function
RAS	-	Rubber Association of Singapore
RMSE	-	Root Mean Square Error
RSS	-	Ribbed Smoked Sheet
SARIMA	-	Seasonal Autoregressive Integrated Moving Average
SR	-	Synthetic Rubber
TOCOM	-	Tokyo Commodity Exchange
TS	-	Time Series
VAR	-	Vector autoregressive
VECM	-	Vector Error Correction Model

Introduction

1. INTRODUCTION

Natural Rubber (NR) is an industrial crude material of vital significance among agricultural products. Over the decades, the significance of NR in day to day life has grown impressively. There are over 50,000 products made out of NR all over the world and 35,000 products from India itself. The cultivation of rubber is the chief means of livelihood for millions of people in many rubber growing countries, who depend directly or indirectly on the wages or profits received from the rubber plantations.

Natural rubber *(Hevea brasiliensis)* is an important cash crop grown in India and it occupies a key position among the plantation crops in the country. India is the sixth largest NR growing country in the world and ranks fourth in production and second in consumption. NR was cultivated in 7.95 lakh ha and the annual production of rubber was 5.62 lakh tonnes in India during 2016 (Rubber Board, 2016). Among the rubber growing states in India, Kerala ranks first, accounting for 80 percent of the NR production.

There are different grades produced from NR which are in turn utilized for various purposes. Among the different grades, RSS-4 is the best grade for export as well as manufacturing purposes. Even though there was a proportionate increase in NR production, the exports are not reaching the expectations because of downfall of crude oil price which in turn increases synthetic rubber production. Increase in production of synthetic rubber is the major constraint for NR producers as synthetic rubber is a substitute for NR (Verico, 2013). High synthetic rubber production is often attributed as the main reason for downfall in NR prices. NR Production in India has been falling sharply, as many farmers are disinclined to take up tapping due to various factors, including low prices, high labour costs and growing imports. At the same time, expansion plans of NR plantations by the major NR producing countries are getting accelerated on account of the rising trend in rubber prices (Mathews, 2011).

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Natural Rubber has been encountering high volatility and instability in prices after the integration of the Indian (domestic) and global markets. Success of price stabilisation policies is dependent upon the efficient assessment of price volatility and price movements (Anuja *et al.*, 2013). The establishment of WTO in 1995 had a significant impact on the extent of integration of the domestic and global markets (Raju, 2016). Persistence of agricultural price instability along with farmer's direct exposure to such fluctuations remains a major concern for policy makers in India.

Before liberalization and globalization, the prices were controlled by the government, but now, the prices are determined by international and domestic market forces. So, there will be greater difference between the behaviour of the prices of NR in the pre-WTO and post-WTO periods which are mainly influenced by the changes in production, consumption, imports and exports, which in turn have become highly varying due to the increased openness in international trade in the era of liberalization. This leads to increased price variability of NR which is detrimental to producers as well as consumers and thus making it imperative to study the behaviour of prices. The price fluctuations are influenced by many factors and hence a proper price forecasts will be helpful to farmers in making informed decisions on production and marketing.

In this context, the present study objectives are as follows:

1. To decompose the prices of Natural Rubber (NR) into time series components
2. To evaluate the growth and instability in prices of NR
3. To study the relationship between international and domestic prices of NR
4. To determine the factors affecting NR prices in pre WTO and post WTO periods
5. To find appropriate model for forecasting the prices of NR

Review of literature

2. REVIEW OF LITERATURE

A detailed review of literature has been carried out and presented in this chapter. The past studies which are interconnected to the present study from the point of the objectives were considered for review. The reviews are classified under the following headings

2.1. Decomposition of time series components

2.2. Volatility AND GARCH model

2.3. Instability index

2.4. Granger Causality

2.5. Cointegration and VECM

2.6. Stepwise regression

2.7. ARIMA and SARIMA Models

2.1. Decomposition of time series Components

Borah and Dutta (1991) studied the wholesale prices of rapeseed and mustard for different markets in Assam. They decomposed the wholesale price data from 1971-72 to 1989-90 into trend, seasonal indices and cyclical variation for which the linear trend equation fitted for the price data revealed the existence of positive trend. Seasonal indices were found to be higher in pre-harvest months than post-harvest months.

Chahal *et al.* (2004) decomposed market arrivals and prices of peas in the main markets (Ludhiana and Hoshpur) of Punjab. They adopted multiplicative model for decomposition of the time series into trend and seasonal variations. They found there was increasing trend in both the markets. Seasonal variations were reported low in the post-harvest period than pre-harvest period due to perishable nature and non-availability of the product.

Yogisha (2005) observed the integration between arrivals and prices of major agriculture commodities in Kolar district, Karnataka during the period from 1994-95 to 2004-05. She found there was an increasing trend for both arrivals and prices of potato, onion and ragi. Seasonal indices proved that arrivals were more at harvesting period and prices were more when arrivals were less. There was negative correlation between arrivals and prices for all the crops.

Gote *et al.* (2010) examined the market arrivals of ground nut from 1996-97 to 2005-06 in Palanpur, Gujarat. They decomposed the data and found that the market arrivals were minimum in the year 2001-02 and maximum in the year 2004-05.

Singh *et al.* (2013) studied the market arrivals and prices of rapeseed and mustard in Bharatpur, Rajasthan, Assam during the period from 1996-97 to 2002-03. By multiplicative decomposition, they found that there was a linear trend in the market price. Seasonal indices revealed that market arrivals were high from February to June and low from July to January.

Jalikatti *et al.* (2013) discussed about the spatial and temporal variations in arrivals and price of onion in North Karnataka from 1996-97 to 2010-11. Four major markets were selected. Markets exhibited linearly increased trend for prices and seasonal indices were found to be high in the months of October and November because of high market arrivals.

Karunakaran (2013) observed a growth trend in cashew crop in Kerala during 1960-61 to 2009-10. He found a downward trend in area and yield after 2000-01.

Dhakre and Bhattacharya (2014) decomposed the monthly average prices of potato in Agra. They fitted sixth degree polynomial regression for finding trend. Seasonal indices were highest in the month of November and lowest in January. For analysing the non-stationary data series and forecasting, ARIMA (2,1,1) model was found to be accurate.

Devi *et al.* (2016) observed the behaviour of chilli prices in Guntur district, Andhra Pradesh for the period from 1977 to 2014. Multiplicative decomposition was used to find out different components of time series *viz.,* trend, seasonal, cyclic and irregular fluctuations. They found an increasing trend in prices in the selected markets and only one cycle which lasted up to four years was observed.

2.2. Volatility and GARCH model

Tain and Guo (2005) deliberated relationship between intraday volatility and trading volume for Shanghai stock exchange from January 2001 to December 2002. They figured out intraday volatility by using GARCH (1,1) model and the results indicated that persistence in volatility remained in the intraday return series even after the lagged log-volume was included in the models as an explanatory variable.

Lokare (2007) endeavoured to test efficiency and performance of commodity prices along with price risk management. He concluded that rubber and black pepper had less volatility and sesame oil, rice and cotton had high volatility for future prices than spot prices.

Jacks *et al.* (2009) explored price data of commodities and manufactures products for three centuries and found that price volatility was always higher for commodities than manufactures.

Bastine *et al.* (2010) assessed the trade performance and transmission of price volatility in black pepper by pair wise and multiple cointegration analyses. They found that there was improved transmission of price signals between domestic and international markets after liberalization. They concluded that the international price transmitted through the export and import values was the major factor responsible for variation in producer prices of black pepper in domestic market.

Kuruvila *et al.* (2012) found volatility for prices in domestic and international markets for four major plantation crops (black pepper, cardamom, tea and coffee) for pre-WTO and post-WTO periods. GARCH (1,1) was adopted to find volatility. They found that volatility of prices for both markets of tea, cardamom and black pepper increased in post-WTO period whereas for coffee price, high volatility was found in early post-WTO period i.e., 1994-2000 and then it decreased in late post-WTO period.

According to Shivakumar (2013) out of the two types of commodities i.e., exchangeable commodity and non exchangeable commodity, the price instability and volatility was more for exchange commodity, except for natural rubber.

Sundaramoorthy *et al.* (2014) examined the volatility of prices in oilseeds and oilseed markets. They obtained volatility by GARCH (1,1) method. With respect to oilseeds, they found that groundnut had high volatility followed by soya bean. Among the different oilseed markets, Hyderabad exhibited the highest volatility.

Rublikova and Hill (2005) observed volatility in quarterly Portuguese imports prices during the period 1976-2004. They tried ARIMA and ARCH models for volatility. ARIMA (3,1,0) and ARCH (2) with the lowest standard errors was tried and found that ARCH (2) was the best for forecasting.

Junior *et al.* (2009) reported behaviour of RSS 1 grade of NR and demand, supply and production at National and International markets from January 1982 to December 2006. They estimated ARIMA-ARCH models for forecasting. Different models were tried and among all AR (1) –GARCH (1) were found best for forecasting.

Paul *et al.* (2009) attempted to study volatility of spices markets in India for the period from April 2000 to November 2006. They found volatility by different methods like ARIMA, GARCH etc. and found GARCH (1,1) as the best among all, on the basis of low RMSE , MAPE and MAE.

Honaro (2014) examined volatiltity in onion and potato from January, 2004 to July, 2014. He found that GARCH (1,1) model was the appropriate volatility model and concluded that there will be increased variance in future.

Saltik *et al.* (2016) found volatility of spot market price of crude oil and Natural gas. They found volatility using different models like GARCH IGARCH, EGARCH, GJR GARCH, TIGARCH and found that GARCH model was the best with minimum loss and maximum returns.

2.3. Instability index

Larson *et al.* (2004) examined the instability of major crops in five main states in India for pre-green revolution and post-green revolution periods. For calculating instability, coefficient of variation was used. The study revealed that the instability increased during post-green revolution period due to new technologies.

Chand and Raju (2008) estimated the instability in three major crops (rice, cotton and ground nut) at the state and district level in Andhra Pradesh for both pre-reform policy (1981-93) and post-reform policy (1993-2004) periods. They found that in both the periods, ground nut showed less instability but area under rice and cotton were highly unstable at the state level on the post-reform period. At the district level, there was no significant difference between the two periods.

Anoopkumar (2012) studied the domestic market instability of five major plantation crops; coffee, tea, natural rubber, black pepper and small cardamom using Cuddy Della Valle instability index. The prices of commodities, *viz.,* natural rubber, black pepper and coffee were reported as exhibiting extreme instability.

More *et al.* (2014) studied the behaviour of market arrivals and prices of soybean in sixteen markets of Maharashtra from 1991-2010. Instability was estimated by Coefficient of variation and found that in all the selected markets arrivals were more instable when compared to prices.

Raju *et al.* (2014) considered instability in foodgrains production at the national and state level for pre-green revolution period (1965-88) and post-green revolution periods (1988-2011) in India. The results revealed high instability in post green revolution period in all aspects like area, production etc. and it was attributed to adoption of new technology.

Ganesan (2015) examined the growth and instability of turmeric production in five selected states of India during the period from 1979-80 to 2010-11. He found significant growth in all the selected states except for area in Andhra Pradesh, production in Andhra Pradesh and Tamil Nadu and yield in Tamil Nadu and Karnataka and attributed the growth to the liberalization measures of 1991.

Rahman *et al.* (2016) examined the price behaviour incorporating price instability and interdependency of different rice market prices in Bangladesh from 1974-75 to 2010-11. They observed that the area instability was due to variation in production, yield and price. The linkage between local markets in Bangladesh was identified by correlation and co-integration. They found that all the markets were integrated of the order (1) and Dhaka was found to be the major market influencing other market prices.

2.4. Granger Causality

Narayan and Smyth (2004) tested causality by co-integration and error correction model for real income, exports and human capital in China for the period from 1960 to 1999. Bidirectional causality was identified between human capital and real exports where as unidirectional causality was found from real income to human capital. Neutrality was maintained between real exports and real income.

Hernandez and Torero (2010) examined the dynamic relationship between spot and future prices of agricultural commodities. Linear and non-linear causality tests were conducted. They found bilateral causality between spot and future prices. Linear causality supported discovery of future prices while non-linear causality provided extra evidence for future prices.

Xu and Sun (2010) compared the effects of two financial crisis (Asian financial crisis sand subprime financial crisis) on the short run and long run linkages between China (mainland and Hong Kong) and U.S. VAR method was used for investigating causal relationships while GARCH-BEKK for analysing volatility spill over. In short run, volatility and causality existed between groups but in the long run, there was no co-integration between mainland with U.S and Hong Kong. During subprime crisis, there was a better interaction between China and U.S.

Mahalle *et al.* (2014) studied decomposition as well as the direction of causation in different markets of Pigeon pea. Decomposition showed that the price behaviour during harvest season was less than non-harvest season and pair wise causality revealed that prices were mostly bidirectional.

Shalini and Duraipandian (2014) derived causal relationship between commodity prices in India for the period from April, 2012 to March, 2013. Mentha oil, jute and wheat prices showed no significant relationship between spot and future prices. The future prices showed significant effect on spot prices only for Rubber.

2.5. Cointegration and VECM

Engle and Granger (1987) provided the relationship between cointegration and error correction models. Estimation of these models was discussed with a two step estimator proposed by them.

Baharumashah and Habibullah (1994) investigated spatial market price relationship among the regional pepper markets by cointegration method. Engle Granger cointegration method revealed a long run relationship between the prices of different markets of pepper.

Gosh (2000) studied the spatial market integration using two methods: Law of One Price (LOP) i.e., perfect co-movement of prices and cointegration. He investigated inter and intra market spatial of rice markets in India. Four different states were taken under the study. LOP was good in UP market for Intra state market integration. For inter-state spatial integration, even though, all markets were integrated, there was no pair wise cointegration. Overall, the intra and inter-state markets were co-integrated with a long run equilibrium.

Rapsomanikis (2004) applied different market integration techniques for wheat and Coffee. He applied Cointegration methods like Engle granger cointergation and Johansen cointegration. These tests were utilized for assessment of market integration and which proved that a policy reform affects price transmissions.

Jayasuriya *et al.* (2007) studied the effectiveness of Indian agricultural policy reforms adopted after overall policy liberalization. He divided the domestic and international prices into two periods: pre-reform period (upto December 1994) and post-reform period (January 1995- December 2002). They proved that these reforms had a large impact on integration of the Indian rice market.

Mukhtar and Rasheed (2010) examined the long run relationship between exports and imports using quarterly data for Pakistan during the period from 1972 to 2006. Johansen Maximum Likelihood method was chosen to check cointegration. VECM was applied for testing the stability of long run equilibrium relationship and direction of causality. They obtained long run equilibrium relationship and bilateral causality. Finally, they concluded that the trade balances were persistent in the long run equilibrium.

Romprasert (2010) discussed cointegration and error correction models for RSS-3 grade of NR in Thailand. He concluded that TOCOM and synthetic rubber consumption; and crude oil price of China have long run equilibrium relationship.

Meerza (2012) employed Johansen cointegration technique to find out whether the nominal exchange rate was cointegrated with macroeconomic variables. She concluded that there was a long run relationship between exchange rate and the variables under consideration.

Reddy (2012) assessed the market integration of chick pea for twelve markets in India from 2003 to 2010. Among all, three markets were integrated indicating weak cointegration. Error correction model indicated that the adjustment process was slow towards long run equilibrium.

Delavari and Alikhani (2013) observed the movement in prices of crude oil, natural gas price and methanol from 2005 to 2013. The results revealed that there in the long-run equilibrium, increase in prices of crude oil and natural gas led to proportional increase in methanol price while in the short-run, this impact is not significant.

More and Deshmukh (2013) observed the prices of sorghum in eight major markets in Maharashtra from January 2004 to December 2014. They observed that all the markets were cointegrated with rank order (1) and found that only Pune and Solapur had long run equilibrium relationship among them.

Zhang (2013) analysed the cointegration between monthly real price of oil and the value of U.S. dollar during the period from January 1973 to June 2010. He observed two structural breaks during November 1986 and February 2005. It was concluded that cointergration between oil price and exchange values will exist if the structural breaks were controlled.

Beag and Singh (2014) investigated wholesale monthly prices in five major markets like Delhi, Ahemadabad, Bengaluru, Hyderabad and Kolkatta in India by Johansen cointegration approach. He derived four cointegrating vectors, with five integrating equations showing long run price equilibrium. Granger causality test was adopted to provide an additional evidence for the flow of information between markets pairs. The test proved that Delhi was the major market for price determination.

Samarpitha (2014) studied the integrated arrivals of chick pea and pigeon pea in Andhra Pradesh from 2006 to 2010 using correlation coefficients. She found that only Medak and Karimanagar were greatly integrated and all others showed negative correlation because of high market price.

Kumar (2015) attempted cointegration of future and spot prices of pepper from 2008 to 2013. The prices were cointegrated with order (1) and had short run equilibrium. He found out a unidirectional causality between prices and forecasted the prices using GARCH method.

Wain *et al.* (2015) attempted investigation on the wholesale weekly prices of three varieties of apple in five regional markets during the period from September 2005 to February 2013. The degree of market integration and relationship were studied by cointegration tests and causality analysis respectively. All the markets were cointegrated and approached a long run equilibrium. He found that there were 18 unidirectional causality and 39 bidirectional causality between markets.

Jishnu *et al.* (2016) studied the market integration between wholesale prices of cotton in eight major producing states in India. They observed that the prices at levels were non-stationary and they became stationary after first differencing. They found that the prices in all the eight major producing states in India were cointegrated and converged to long run equilibrium.

Nkoro and Uko (2016) found that when there are more than two variables to be dealt with, Johansen Julius method is preferable. Trace and Maximum Eigen value tests were the two likelihood ratio test statistics which were taken into consideration to detect the number of cointegrating vectors.

2.6. Stepwise Regression

Khin *et al.* (2011) developed a short term econometric model of SMR-20 for the period from January 1990 to December 2009. Both single and simultaneous equations were used to forecasts and simultaneous supply-demand price equations with low RMSE, MAPE criteria were more accurate than single equation models.

MdLudin *et al.* (2016) identified the important factors that affects NR Industry in Malaysia by two stage least square method. They developed an equation by using variables like production, import, domestic price, consumption, exports and world price. Results proved that production depends on the time trend, area and one year lagged production natural rubber.

2.7. ARIMA and SARIMA models

Rangoda *et al.* (2004) studied the instability of coconut and coconut product prices in Sri Lanka from the period January 1974 to December 2004. He analysed the data using six standard time series models like moving average method, decomposition method, Holts winter method, single exponential smoothening, double exponential smoothing and ARIMA. He compared all these models using MAPE, MAD and MSD in which he found that ARIMA and single exponential smoothening methods were the best for forecasting of wholesale prices.

Menon *et al.* (2006) forecasted cardamom prices by employing ARIMA (2,1,0) model using monthly prices from January 1985 to December 2005. ACF and PACF were used for identifying the parameters of the model. The prices series were checked for stationarity, independence of residuals and significance of autocorrelations and short term price forecasting was done for five months from August 2005 to December 2005.

Jeethu (2011) studied the price behaviour of cashewnut in India and Bangkok markets based on monthly data from 1965-66 to 2010-11. Several models like single and double exponential smoothening models, ANN and Box-Jenkins ARIMA models were tried for forecasting price of cashew nut. ARIMA (3,1,0) $(0,1,1)_{12}$ was identified for Bangkok market as best model with least MAPE of 5.12 whereas ARIMA(0,1,1) was best for domestic market with least MAPE of 2.73 when compared to other models.

Khin *et al.* (2011) examined different short term forecasting models MARMA and VECM and ARIMA models for SMR-20 NR prices in Malaysia for the period from January 1990 to December 2008 and found that MARMA to be the best fit model.

Reeja (2011) compared ARIMA models for forecasting price NR (RSS-4) in Kottayam and Bangkok with different forecasting models. SARIMA (0,1,0) $(1,0,1)_{12}$ developed for price in Bangkok market was found to be the best model.

Adanaliglu and Yercanm (2012) analysed the seasonal price variation of tomato at Antalya, in Turkey by using Seasonal ARIMA (SARIMA). Out of many models tried, SARIMA $(1,0,0)(1,1,1)_{12}$ model was identified as the best to forecast wholesale monthly price of tomato. The data from January 2000 to December 2010 was used and forecast was made up to 2014 December.

Sakanin (2012) analysed the price of NR in Malaysia. Univariate ARIMA model and multivariate Vector Auto Regression (VAR) model were used to forecast the prices using data from January 2000 to September 2011. Among the models tried ARIMA (1,1,2) and VEC model provided the least RMSE and MAE values.

Arumugam and Anithakumari (2013) attempted to forecast the monthly production of NR in India using data from January 1991 to December 2012. Additive decomposition model was suggested for decomposition and linear trend in production was observed. For forecasting production, Seasonal ARIMA (2,1,2) $(1,1,1)_{12}$ model was identified as the appropriate model to forecast.

Krishnakutty (2014) attempted different ARIMA models for forecasting annual current prices of teak in girth classes 1,2,3 for Kerala state. He forecasted the prices of girth classes 1,2,3 with ARIMA(1,2,1), ARIMA(0,2,2) and ARIMA(0,2,2) respectively within 95% confidence limits.

Tajdini *et al.* (2014) forecasted the annual prices of wood based panels in Iran from 1986 to 2009. He used the forecasting methods like ARIMA, Holt's

Winter and exponential methods. Among these measures, ARIMA (2,1,1) was found to be best with low RMSE for Veenar wood panel.

Jalikatti and Patil (2015) attempted to forecast monthly prices of onion in Hubli District of Karnataka for the period from 1996-97 to 2010-11. ARIMA (1,1,1) $(2,1,1)_{12}$ was found to fit the series, in which AIC and Q-statistic were found to be non-significant. He forecasted for the next two years i.e., up to 2013.

Cherdchoongam and Rungreunganum (2016) forecasted NR prices in Thailand using ARIMA, SARIMA and ARIMAX. They used the monthly data from January 2002 to December 2014. ARIMA (1,0,1) was identified as best among all the models and the prices were forecasted for next 12 months i.e., January 2015 to December 2015 prices.

Yashavanth *et al.* (2016) tried non-parametric time series (FCAR) and parametric time series modelling (ARIMA) for prices of coffee seeds in Hyderabad by fitting FCAR (2,2) and ARIMA (12,1,0) models. He found that FCAR (2, 2) was the best model by means of low values of measures like RMSE, AIC and BIC criterion.

Materials & Methods

3. MATERIALS AND METHODS

The database methodology used in the study and statistical techniques used are for the present study discussed below

3.1. Database for the Study

Monthly average of Indian NR prices, International NR prices and crude oil prices were chosen for the study. Indian NR prices published by Rubber board, Kottayam were used for the study. International rubber prices and crude oil prices were collected from the world pink data. Details of data collected for the study are presented in the Table 3.1.

Table 3.1: Details of data collected for the study

Notion of Data	Period	Market	Source
Domestic NR prices (RSS-4)	From 1980 January to 2016 December (monthly average)	Kottayam	www.rubberboard.org .in
International NR prices (RSS-4)	From 1980 January to 2016 December (monthly average)	Malaysia	www.worldbank.org
Crude oil prices	From 1980 January to 2016 December (monthly average)	United States	www.worldbank.org
Domestic NR production, consumption, import, SR production and consumption (RSS-4)	From 1980 to 2016 (annual average)	Kottayam	www.rubberboard.org .in

3.2. Statistical techniques

3.2.1. Time plot

The most important step towards exploring Time series (TS) data is to envision the data through graphs or plots. The graph obtained by plotting time series data against the corresponding time of occurrence is called time plot. Time plot helps to understand the pattern of the TS and to identify the presence of any trend over time, any seasonal behaviour and other systematic features of the data.

3.2.2. Decomposition model for price data

Additive model was assumed for the TS of Rubber prices. Let Y_t be the price at time t. Then Y_t is given by

$$Y_t = T_t + S_t + C_t + I_t$$

Where, T_t is the trend value at time t

S_t is the seasonal variation at time t

C_t is the cyclic variation at time t

I_t is the random fluctuations at time t

The TS components are explained in brief

Secular trend (T_t)

Over a long period, time series is very likely to show a tendency to increase or decrease over time and is called as trend. There are two types of trends viz., linear and non- linear trend.

Seasonal variation (S_t)

Seasonal variations are the periodic and regular movements in TS with period less than a year. Monthly, quarterly or weekly data are considered to study seasonal variation. In the present study, monthly data is used.

Monthly Seasonal indices were calculated by

$$\text{Seasonal index} = \frac{\text{Moving Average for X month}}{\text{Average of Moving Average}} \times 100$$

Cyclical variation (C_t)

Cyclical variations are fluctuations, which differ from periodic movements, in that they are of longer duration than a year and have a periodicity of several years as in business cycles. Usually, a cycle lasts from 2-8 years (Gujarati *et. al.,* 2015).

3.2.3. Volatility

The notion of volatility is usually associated with financial TS. Volatility is the degree of variation of a price series over time usually measured through standard deviation. The phenomenon of volatility clustering arises when in certain periods; prices exhibit wide swings for an extended period followed by period comparatively lower swings.

Two types of volatility clustering are discussed in this study. They are:

3.2.3.1. Intra-annual volatility

Gilbert (2006) examined the extent of volatility of some commodities and the temporal evolution of the volatility was analysed by constructing a series of annual observations from monthly data by using intra annual standard deviation of changes in log prices.

The intra-annual volatility in monthly prices was measured as the intra-annual standard deviation of changes in log prices, which is defined as

$S_Y = \sqrt{1/11} \sum_{m=12}^{12}(\ln P_{y,m} - \ln P_{y,m-1} - \delta y)^2$ for year 'y',

where, $\delta_y = 1/12(\ln P_{y,12} - \ln P_{y,0})$ is the y^{th} year drift

and $P_{y,0} = P_{y-1,12}$.

$P_{y,m}$ is the monthly price in the month m, in year y.

$P_{y,m-1}$ is the monthly price in the month m, in year y.

This estimate is scaled onto an annual basis using the factor of $\sqrt{12}$

3.2.3.2. Inter-annual volatility

Inter annual volatility is calculated by using the formula

$S_{p,y} = (\ln P_y - \ln P_{y-1})^2$

Where, P_y is the average price in a year $y_{,s}$

$\mathbf{P}_{y-1}$ is the average price in year y-1.

$S_{p,y}{}^2$ is the measure of volatility

3.2.4. Testing for Volatility (GARCH Model)

Generalized Autoregressive Conditional Heteroscedasticity (GARCH) Models distinguish the predictable and unpredictable components of prices and also allows the variance of the unpredictable element to be time varying. Such time varying conditional variances was estimated by using GARCH (1,1) model (Bollerslev, 1986) and were used to identify periods of high volatility.

GARCH (1,1) Models is $Y_{it} = a_0 + b_1 Y_{it-1} + b_2 Y_{it-2} + \varepsilon_{it}$

$$\sigma_{i,j}^2 = \theta + \alpha_i \varepsilon_{i,t}^2 + \beta_i \sigma_{i,t}^2$$

Where, Y_{it} is the price index in time t of i^{th} commodity

$\sigma^2_{i,j}$ is the error variance in time t of i^{th} commodity

$(\alpha_i+\beta_i)$ gives the degree of persistence of volatility in price series

If $(\alpha_i+\beta_i)$ is closer to 1, greater is the tendency of volatility to persist for longer time and if the sum exceeds 1, it is indicative of an explosive series with a tendency to meander away from mean value.

GARCH (p,q) Model is

$$\sigma_{i,j}^2 = \omega + \sum_{i=1}^{p} \beta_i \sigma_{t-1}^2 \sum_{i=1}^{q} \alpha_i \varepsilon_{t-1}^2$$

3.2.5. Instability in prices

In order to study the variability in NR prices, an instability index was developed as a measure of variability. In the present study, Cuddy Della Valle Index measure was taken into account.

3.2.5.1. Cuddy Della Valle Index

The magnitude of instability in the prices of rubber was measured in relative terms by Cuddy Della Valle Index which is used as a measure of variability in time-series data (Cuddy and Della, 1978). It is a modified version of coefficient of variation (CV) so as to accommodate the trend present in the series.

It is said to be superior to other estimates because the simple coefficient of variation overestimates the level of instability characterised by the long term trends, whereas Cuddy Della Valle Index corrects this. Formula is given as,

Cuddy-Della Valle Instability Index (%) = C.V $\times \sqrt{(1-R^2)}$

Where, CV is the coefficient of variation in per cent,

R^2 is the coefficient of determination from trend regression adjusted by the number of degrees of freedom.

3.2.6. Cointegration

3.2.6.1. Testing for stationarity

First step in cointegration is to find whether the data is stationary or not and to test whether there are one or more unit roots in the data - whether the individual series are I(1). Analysing the stationarity using Augumented Dickey Fuller (ADF) test at the beginning is necessary, because if the variables are non stationary, there is every possibility of misleading results.

ADF test is used when there is autocorrelation in the dependent variable Δy_t, the error term will also be autocorrelated, because the omitted lags of Δy_t will be a part of it. To control for the possible autocorrelation, the basic equation for this test has to be expanded with p lags of the dependent variable Δy_t (Enders, 2008). By including lags of the dependent variable, its potential autocorrelation is absorbed, the error term is now a white noise process and usual Dickey-Fuller (DF) test statistics and critical values can be used. This test is known as the ADF test and will be used further in the cointegration analysis of the prices, to ensure that the error terms are white noise processes. The Hypothesis for ADF test is:

H_o: $\rho = 0$ ($\beta = 1$)

H_1: $|\rho| < 1$ ($\beta < 0$)

Expanding the basic equation with lags of the dependent variable also leads to the issue of the number of lags to include. Including too few lags can result in some of the autocorrelation to remain in the model.

There are various methods to choose the optimal number of lags. For the ADF test, the Akaike information criterion (AIC) will be used. The number of lags that minimizes the AIC value is the optimal lag length, where

$$AIC = \log |\Sigma^{\wedge}| + \frac{2k}{T}$$

where, $\Sigma^{\wedge}$ is the variance-covariance matrix of residuals, T is the number of observations and k is the number of coefficients in equation (Davidson and MacKinnon, 2001).

3.2.6.1.1. The Johansen method

Johansen method is used for cointegration analysis. There could be more than one cointegrating vector in a system of variables and the Johansen method can discover all such cointegrating relations [Johansen and Juselius (1990)]. The Johansen method relies on a vector autoregression (VAR) model.

A VAR is a system regression model which includes more than one dependent variable. Every variable is regressed on a combination of its own lagged values and lagged values of other variables from the system. Here, the simplest form is presented, where k denotes the number of lags included (Brooks, 2008)

$$y_t = \beta_1 y_{t-1} + \beta_2 y_{t-2} + \dots\dots\dots + \beta_k y_{t-k} + u_t$$

To use the Johansen test, the VAR model needs to be transformed into a vector error correction model (VECM), by differentiating:

$$\Delta y_t = \sum_{i=1}^{k} \Gamma i \ \Delta y_{t-1} + \Pi y_{t-k} + \mu + \beta t + \varepsilon_t$$

where, there are g variables in the model and k-1 lags of the dependent variables. Γ is the coefficient matrix for every lagged variable and Π is the long-run coefficient matrix.

This VECM is estimated by Maximum Likelihood Estimation method, not OLS estimation as for the Engle-Granger method. The Johansen test is a multivariate case of an ADF test for unit root. The focus in this method is on the

Π matrix - test the rank (r) of this matrix is tested. The rank is equal to the number of characteristic roots (eigenvalues, denoted by λ), that are significantly different from zero. That means that the rank (r) will give us the number of cointegrating vectors in a system of variables.

There are three possible cases, based on the rank of the Π matrix (Johansen and Juselius, 1990)

full rank (r = g) - all eigen values are significantly different from zero, implying that the original variables are stationary and therefore cointegration is not possible.

rank is zero (r = 0) – none of the eigen values are significantly different from zero, implying that there are no linear combinations of variables that are I(0), and thus no cointegration.

reduced rank (0 < r < g) – there are r linear combinations of variables that are I(0), meaning that cointegration exists in this system, with r cointegrating vectors.

In the Johansen method, two tests are used to detect cointegration and the number of cointegrating vectors (Enders, 2008)

3.2.6.1.1.1. The Trace test

Trace statistics (λ-trace) = -T (1-λ_i)

The null hypothesis of r or less than r cointegrating vectors is tested against the alternative of more than r cointegrating vectors.

3.2.6.2.1.2. The Maximum eigenvalue test (the Max test)

Maximum Eigen value statistics (λ-max) = -T ln (1-λ_{r+1}).

The null hypothesis of exactly 'r' cointegrating vectors is tested against the alternative of r+1 cointegrating vectors. r is the number of cointegrating vectors, i is the estimated eigen value of order i from the Π matrix, and T is the number of observations. The distribution of the two test statistics is not standard and the critical values depend on the value of (g – r) and the deterministic terms included (Johansen and Juselius, 1990). If the test statistic is larger than the appropriate critical value, the null hypothesis of no cointegration is rejected.

If a reduced rank is detected, find cointegration with r cointegrating vectors, the Π matrix can be defined as a product of two matrices: where α is a (g × r) matrix and β is a (r × g) matrix. The β matrix shows the cointegrating vectors while the matrix α shows the amount of each cointegrating vector in the VECM, or the adjustment coefficients. The critical values of the Johansen method are sensitive to the lag length and the number of deterministic terms in the VECM. Therefore it is important to choose the optimal lag length and whether a constant term and/or a time trend should be included.

3.2.7. Granger causality test

Granger causality is an econometrics tool to determine whether one time series is useful to predict the future of another series based on the standard F-test framework. A variable X Granger-causes Y if the past changes of X could help to predict current changes of Y. If X Granger-causes Y and not vice versa. If X Granger causes Y and Y also Granger causes X, it would be said that there is bi-directional causality between (Brooks, 2008).

The null hypothesis for the Granger test in the above equations is X does not cause Y; the alternative is X causes Y. If the null hypothesis is rejected, the conclusion that X Granger causes Y is obtained (Roca, 1999).

It should be noted that Granger-causality really represents only a correlation between the current value of one variable and the previous values of others. It doesn't mean that movements of one variable cause movements of another

(Brooks, 2002). Moreover, although causality examines whether the current value of variable X can be explained by the past values of variable Y, it still does not explain the sign of the relationship or how long these effects last (Granger and Newbold, 1994).

3.2.8. Stepwise regression Method

Stepwise multiple regression is a blend of the forward and backward selection techniques.

3.2.8.1. Backward Selection

At each step, the variable that is the least significant is removed. This process continues until no non-significant variables remain.

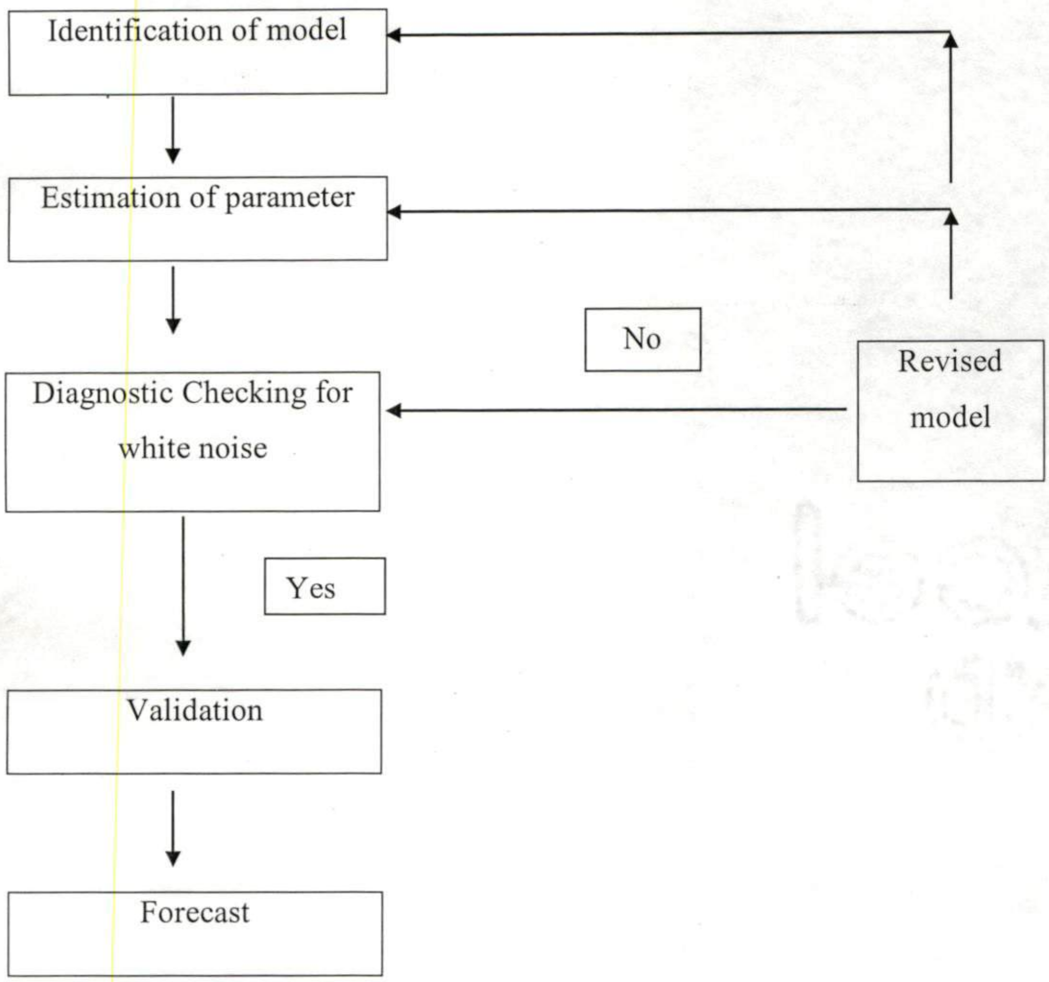
3.2.8.2. Forward selection

It starts with no variables in the model. Later on, the variables are added. At each step, select the variable that increases R-Square the most. When none of the remaining variables are significant, stop adding variables.

Modification of forward selection is Stepwise regression. In stepwise regression, in each step a new variable is added and tests their significance level. If a non-significant variable is found, it will be removed from the model. Two significance levels are checked: After adding variables and after removing the variables.

3.2.9. ARIMA methodology

Framework of ARIMA model is as follows:



3.2.9.1. Identification

The purpose of this step is, to select a specific ARIMA Model from the general class of ARIMA (p, d, q) process.

where, p = order of non-seasonal auto regressive (AR)

d = order of non-seasonal difference

q = order of non-seasonal moving average (MA);

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The choice of the appropriate p and q values require examining the autocorrelation and partial autocorrelation coefficient calculated for the data. A good starting point for time series analysis is a graphical plot of the data. It helps to identify the presence of trend.

Before estimating the parameters (p, q) of the model, the data are not examined to decide about the model which best explains the data. This is done by examining the sample Auto Correlation Function and Partial auto Correlation Function of the differenced series of Y_t. Usually ACF and PACF are calculated up to a maximum of 26 lags (k).

The sample auto correlations for k time lags can be found and denoted by r_k as follows

$P_k(Y_t) = r_k(Y_t)$

$e_k(Yt)/e_0(Y_t)$

Where, $e_k(Y_t) = 1/i\sum_{t=1}^{t}(Y_t - \bar{y})(Y_{t+k} - \bar{y})$

$k = 0, 1, 2 \ldots 24$

t= time period

Both ACF and PACF are used as the aid in the identification of appropriate models. ACF models were used to identify the MA terms and PACF are used to identify AR terms. There are several ways of determining the order type of process, but still there is no exact procedure for identifying the model.

Yet another application of the autocorrelation function is to determine whether the data contains a strong seasonal component. This phenomenon is established if the autocorrelation coefficients at lags between t and t_{12} are significant. If not, these, coefficients will not be significantly different from zero.

3.2.9.2. Estimation of parameters

After identifying the suitable model, next step is to obtain least square estimates of the parameters such that the error sum of squares is minimum.

To estimate φ and θ, it is first necessary to work out the moving average process to estimate θ and then perform analytical least squares to estimate the autoregressive parameters.

The sum of the squares are obtained as,

$$S(\varphi, \theta) = \sum_{t=1}^{n} e_t^2(\varphi, \theta)$$

where, t = 1, 2, 3… n.

The sum of the squares can be then plotted for a grid value of θ and φ the final value that minimize S (θ). Then preliminary value of the tentatively identified model are obtained by using the sample ACF as proxy for Y(k) and solved for φ and θ. Then, by an iterative process, we obtained the maximum likelihood estimate of θ can be obtained and φ can be obtained by minimizing the sum of squares.

To estimate the parameters, there are two fundamental ways viz., Trial and error method and Iterative method

3.2.9.3. Diagnostic checking of the model

After having estimated the parameters of a tentatively identified ARIMA model, it is necessary to do diagnostic checking to verify that the model is adequate.

Examining ACF and PACF of residuals may show up an adequacy or inadequacy of the model. If it shows random residuals, then it indicates that the tentatively identified model is adequate. When an inadequacy is detected, the checks should give an indication of how the model need be modified, after which further fitting and checking takes place.

One of the procedures for diagnostic checking mentioned by Box-Jenkins is called over fitting i.e., using more parameters than necessary. Over fitting involves fitting a more elaborated model than is indicated by the identification procedure. However, the main difficulty in the correct identification is not getting enough clues from the ACF because of inappropriate level of differencing. The residuals of ACF and PACF considered random when all their ACF are within the limits ± 1.96 Sqrt (1/ n –12)

Ljung and Box "Q" statistic is also used to check whether the auto correlations of the residuals are significantly different from zero. It can be computed as follows.

$$Q = n(n+2) \sum_{k=1}^{h} (n-k)^{-1} r_k^2$$

Where, h = Maximum lag considered

n = Number of observations

r_k = ACF for lag k

m=p+ q = Number of parameters to be estimated.

In addition, Q is distributed approximately as a Chi-square statistic with (h-m) degree of freedom.

The minimum Akaike Information Coefficient (AIC) criteria is used to determine both the differencing order (d, D) required to attain stationarity and the appropriate number of AR and MA parameters (Gujarati *et al.,* 2015). It can be computed as follows;

$$AIC \cong n\,(1 + \log(2\pi)) + n \log\sigma^2 + 2m .$$

where, σ^2 = Estimated MSE

n = Number of observations

m= Number of parameters to be estimated (p+q)

This diagnostic checking helps us to identify the differences in the model, so that the model could be subjected to modification, if need to be.

3.2.9.3.1. Root mean square error (RMSE)

The Root Mean Square Error (RMSE) (also called the root mean square deviation, RMSD) is a frequently used measure of the difference between values predicted by a model and the values actually observed. These individual differences are also called residuals, and the RMSE serves to aggregate them into a single measure of predictive power.

The RMSE of a model prediction with respect to the estimated variable X_{model} is defined as the square root of the mean squared error:

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}(X_t - X_{model,t})^2}{n}}$$

Where, X_{obs} is observed values and X_{model} is modelled values at time t.

3.2.9.4. Validation

The procedure of validation is to estimate the already known data values for a particular period and to compare the original values and estimated values and conclude whether the estimate of the parameter is accurate or not. In this present study, six months data was taken for validation.

3.2.9.5. Forecasting

If the parameter estimates give accurate values for the validate data, forecast will be done using the particular parameter.

In the present study, ARIMA (4,1,4) was found appropriate model to forecast and the model is represented as:

$$(1-\phi_1B-\phi_2B^2-\phi_3B^3-\phi_4B^4)\ (1-B)\ y_t = (1-\theta_1B-\theta_2\ B^2-\theta_3B^3-\theta_4B^4)\ \varepsilon_t$$

3.2.10. SARIMA

SARIMA is termed as Seasonal Auto regressive Integrated Moving Average (Seasonal ARIMA). Almost, SARIMA also has the same framework as ARIMA except for the estimation of the seasonal parameters and is termed as ARIMA (p, d, q) (P, D, Q)s

p = order of non-seasonal auto regressive (AR); P = order of seasonal auto regressive (SAR); d = order of non-seasonal difference; D = order of seasonal difference; q = order of non-seasonal moving average (MA); Q = order of seasonal moving average (MA); S = length of the season.

In this study, ARIMA (4,1,4) $(1,0,1)_{12}$ was estimated appropriate model to forecast the prices and model is given as:

$$(1-\phi_1B-\phi_2B^2-\phi_3B^3-\phi_4B^4)\ (1-\Phi_1B^{12})(1-B)\ y_t=(1-\theta_1B-\theta_2\ B^2-\theta_3B^3-\theta_4B^4)+(1-\Theta_1B^{12})\varepsilon_t$$

Results & Discussion

4. RESULTS AND DISCUSSION

The results of the study along with interactive discussions are presented under the following headings.

4.1. Overview of the domestic Natural Rubber, international Natural Rubber and crude oil prices

The data on domestic and international prices of Natural Rubber (NR) and crude oil prices for the period from January 1980 to December 2016 were collected for the present study. The range of prices for the domestic NR, international NR and crude oil were Rs.1005-23868, Rs.787-28358 and Rs.12095 -701860 respectively which depicts the intrinsic price variations. The plots (Figure 1) of all the three commodity prices affirm the price variations. From the Figure, it is natural to infer the integrated movement of the prices could be observed. A time series data is usually visualized to be made of four components. They are secular trend, seasonal variation, cyclical fluctuations and irregular variations.

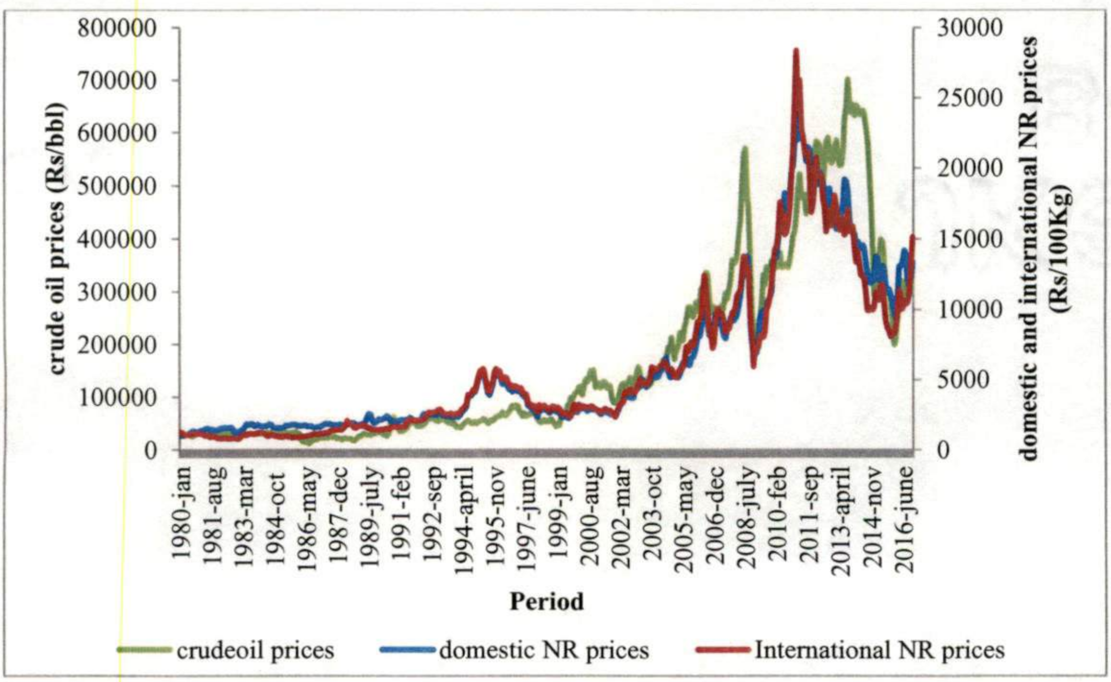

Figure 1: Time plot of domestic NR, international NR and crude oil prices

Filtering the four components from the core data is usually achieved through a mathematical relationship. The relationship usually hypothesised shall be of two types. They are:

Additive decomposition

Multiplicative decomposition

The model assumptions of the above models a and b are

$Y_t=T_t+S_t+C_t+I_t$ and $Yt=Tt*St*C_t*I_t$ respectively

Where, Y_t is the original time series data

T_t is the secular trend

S_t is the seasonal factor

C_t is the cyclical fluctuations

I_t is the irregular component.

In the present study, the terms $C_t + I_t$ were coined as E_t which is regarded as the white noise term and the additive and multiplicative models, turned out to be $Y_t=T_t+S_t+E_t$ and $Y_t=T_t*S_t*E_t$ respectively. For a time series data, the error structure will depict the presence of serial relationship. The adequacy of the model shall be ascertained through Autocorrelation function (ACF) and Partial autocorrelation function (PACF) plots where the underlying pattern of the ACF and PACF plots of the error terms under the assumption of multiplicative relationship showed serial dependences. As such the analysis based on multiplicative model is not justified. Hence the fit through the additive model was investigated. However, ACF and PACF spikes showed very few spikes. In terms of vigorous statistical inference this model is also not adequate. The next alternative shall be compound model, the same being not investigated further due to time constraint and the major objective being a deviate from decomposition analysis.

Thus, under the assumption that the data follows an additive structure with respect to the components, the trend and seasonal components were found using R package. The results are presented in the Figure 2 and 3.

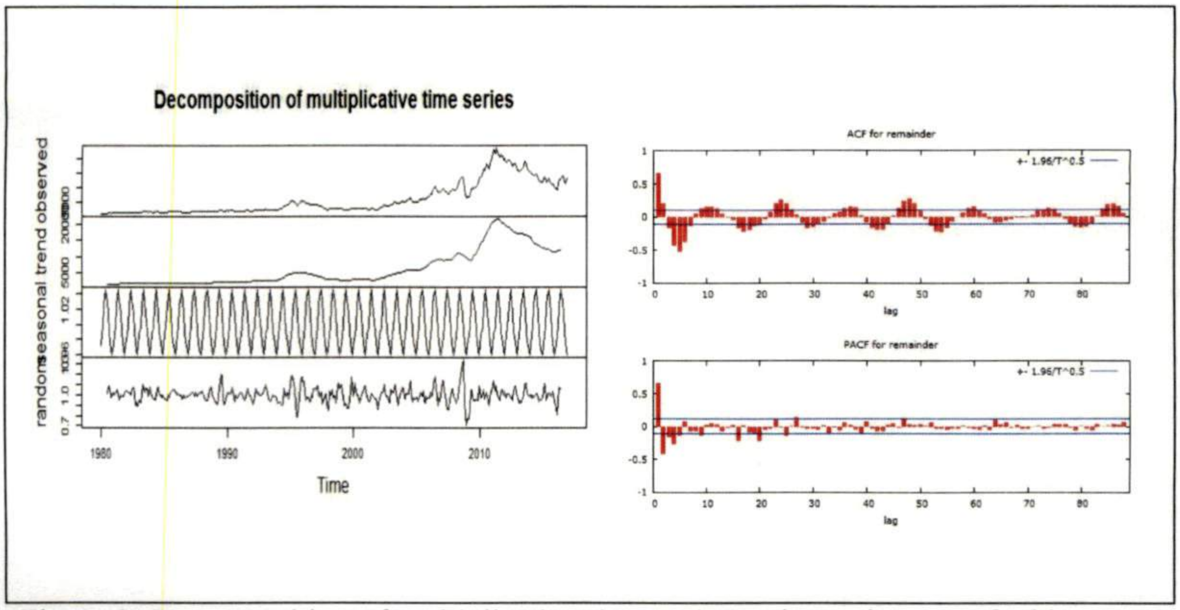

Figure 2: Decomposition of multiplicative time series and correlogram of white noise for domestic NR price

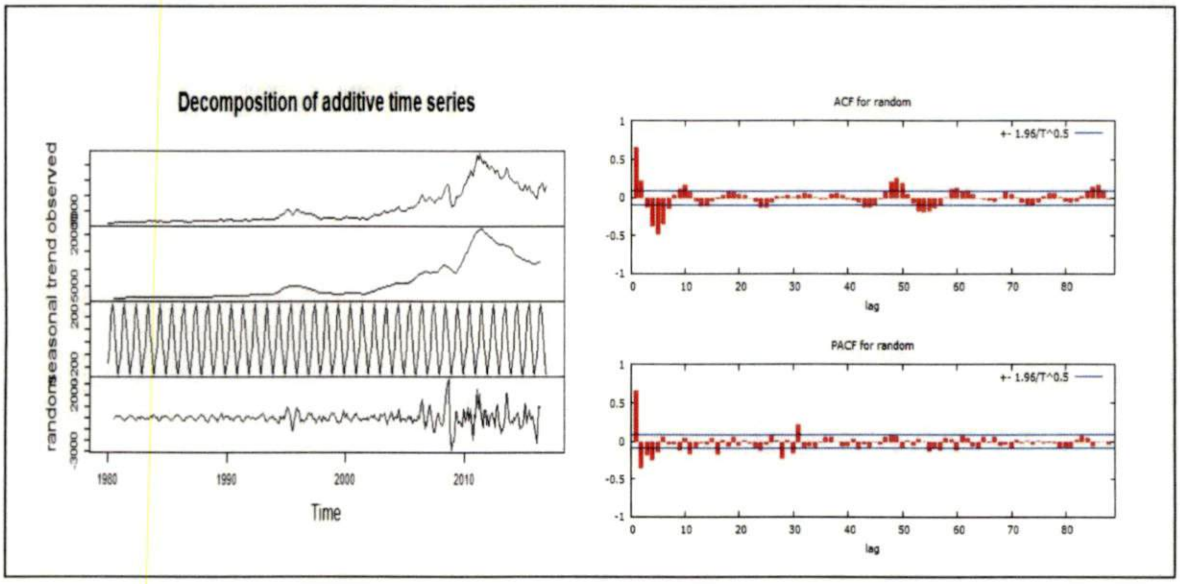

Figure 3: Decomposition of additive time series and correlogram of white noise for domestic NR price

The pattern of the data as shown in Figure 4 showed considerable quantum of instability in prices of the trend. The prices showed an increasing trend from October 1983 to September 2008. There was a sudden fall down of NR prices from October 2008 decreased upto March 2009. From that point, it increased upto November 2011 and then onwards there was a fall in prices till February 2016. From that point, the prices started increasing from February 2016 to December 2016. Since there was no improvement at all in R^2 for cubic model, the best fit of the model was taken as quadratic model (Table 4.1).

The fitted trend equation was as follows:

$$Y_t = 2439.3 - 23.8 \times t + 0.14 \times t^2$$

Though, there was rejuvenation in trade in general, in the immediate years after WTO period, the sustenance of such a tempo gradually scaled down in the later years of post WTO period which could be attributed to increased imports and competition as the implications of free trade policy.

Table 4.1 Linear, quadratic and cubic regressions summary for trend of NR prices.

Equation	**R Square**	**Constant**	**b1**	**b2**	**b3**
Linear	0.69	-2183.3	36.8		
Quadratic	0.81	2439.3	-23.8	0.14	
Cubic	0.81	2796.3	-32.8	0.19	-0.0007

The trend values are tabulated in Appendix 1.

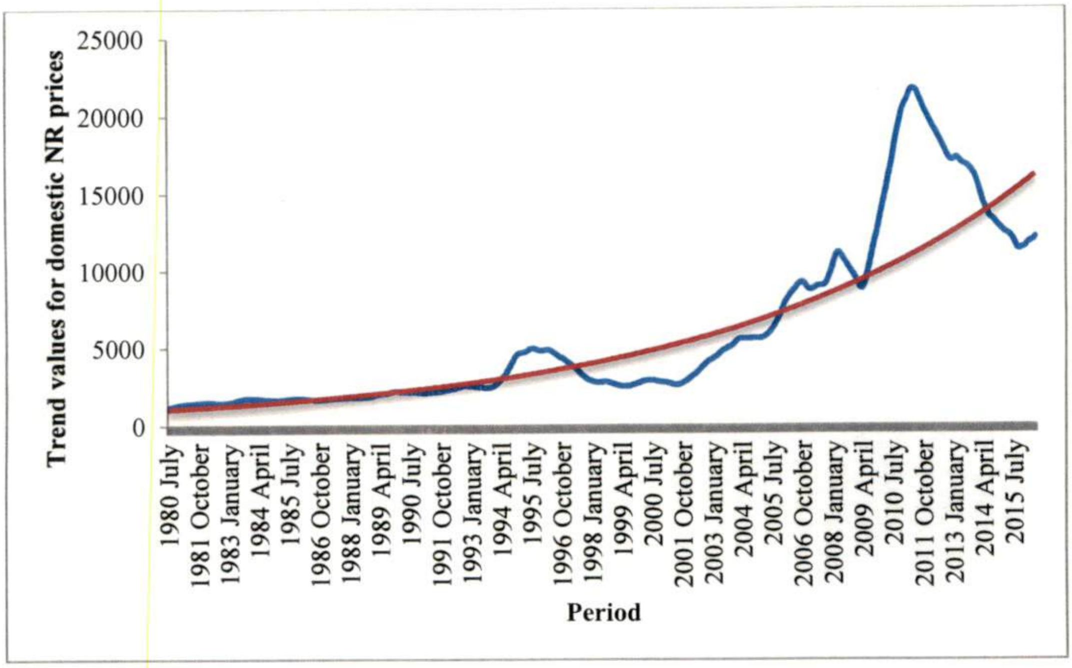

Figure 4: Graph representing the quadratic trend value for domestic NR prices.

4.1.2. Seasonal Variation

The estimated monthly seasonal indices are presented in Table 4.2. With an ascendency from January, the seasonal index, was highest in June and there after more down continuing to December and thereafter it showed reversal in pattern and it increased upto June. This might be possibly due to the fact that the peak production is in the month of December. The usual tendency of the production is to increase from October and it continues up to January followed a by slag in production from February to May which attains peak in June. Figure 5 represents graph of monthly seasonal indices.

Table 4.2 Monthly seasonal indices of domestic NR prices

Month	Seasonal indices
January	97.35
February	98.93
March	99.51
April	102.39
May	104.05
June	104.13
July	103.17
August	101.35
September	98.50
October	97.69
November	96.72
December	96.22

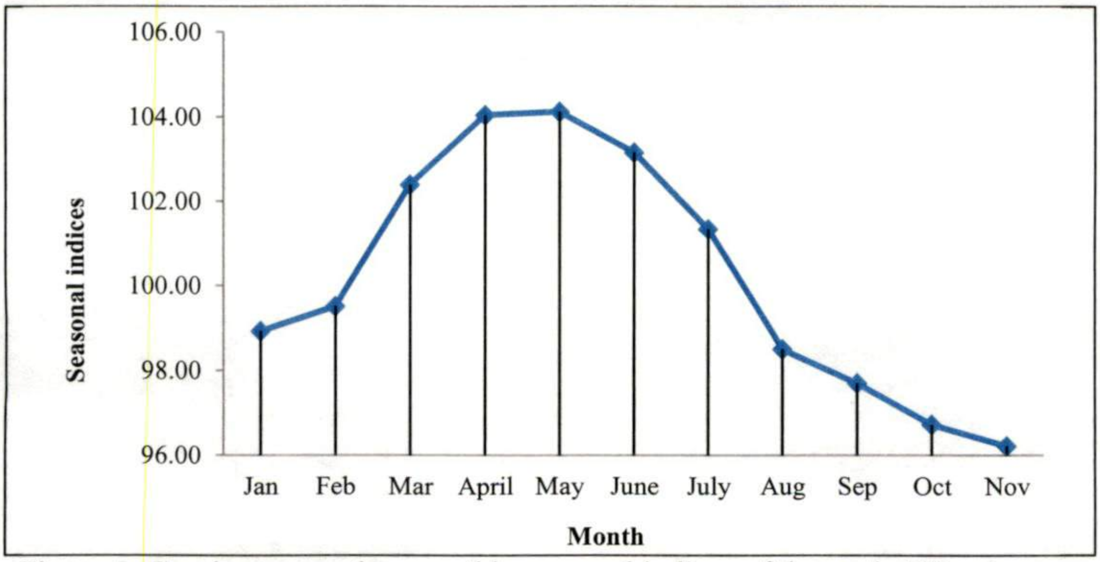

Figure 5: Graph representing monthly seasonal indices of domestic NR prices

4.1.3. Cyclical fluctuations

From Figure 6, three cycles can be read: Cycle I extending from 1980 to 1993, Cycle II from 1993 to 2000 and Cycle III from 2000 to 2015. The nature of the cycles is affirmative of the non-stationary behaviour of the time series.

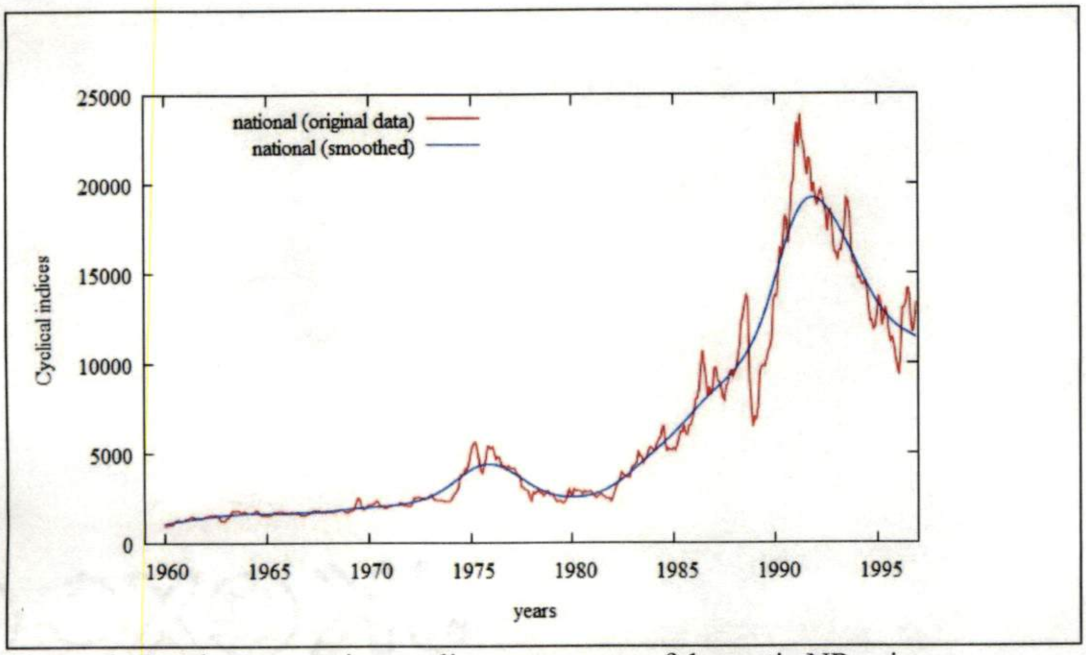

Figure 6: Graph representing cyclic components of domestic NR prices

4.2. Evaluation of Growth and Instability

The growth and instability of NR was assessed through volatility and instability analyses. Volatility was calculated to find out the price dispersion over a period of time and instability analyses was carried out for knowing the rate of instability among the prices.

Volatility

There are two types of volatility calculated in this study, intra-annual volatility (within year dispersion) and inter annual volatility (between year dispersion). They are as follows:

4.2.1. Intra-annual volatility

Intra annual volatility for monthly prices of domestic NR, international NR and crude oil prices were calculated to measure within the year dispersion.

The results of intra annual volatility and their respective graphs are given in Table 4.3 and Figure 7. It could be observed from the table the volatility in the overall period, in terms of rupees, ranged from 0.17 to 1.26, 0.16 to 1.27 and 0.13 to 1.77 for domestic NR, international NR and crude oil prices respectively. Range of intra annual volatility was higher in post-WTO than pre-WTO for domestic NR and international NR price series. In the post-WTO period, 2008 exhibited the highest volatility while in the pre-WTO period volatility was highest in 1989. When compared to domestic NR prices, international NR prices showed more volatility in pre-WTO but it settled with domestic NR prices in post-WTO. Crude oil price series showed wide fluctuations in volatility in pre-WTO than post-WTO period.

The volatility in terms of dollars is depicted in Table 4.3 and Figure 8. From the table, it could be observed that the range of volatility for prices in US dollars was almost equal to volatility in terms of rupees. It ranged from 0.17 to 1.26, 0.12 to 1.29 and 0.13 to 1.76 for domestic NR, international NR and crude oil price series respectively. Intra-annual volatility was higher in post-WTO than pre-WTO for domestic as well as international NR prices. Crude oil prices showed high volatility in pre-WTO than post-WTO period.

Table.4.3 Intra-annual Volatility indices of monthly domestic NR, international NR and crude oil prices

Commodity/ Price	Pre-WTO	Post-WTO	Overall period
In rupees			
Domestic NR price	0.17 - 0.75	0.25 - 1.26	0.17 - 1.26
International NR price	0.16 - 0.67	0.29 - 1.27	0.16 - 1.27
Crude oil price	0.13- 1.77	0.35 - 1.35	0.13 - 1.77
In US dollars			
Domestic NR price	0.17 - 0.74	0.29 - 1.35	0.17 - 1.35
International NR price	0.12 - 0.64	0.27 - 1.29	0.12-1.29
Crude oil price	0.13 - 1.76	0.27 - 1.38	0.13-1.38

Note: Figures denote range of volatility indices for each of the category of prices

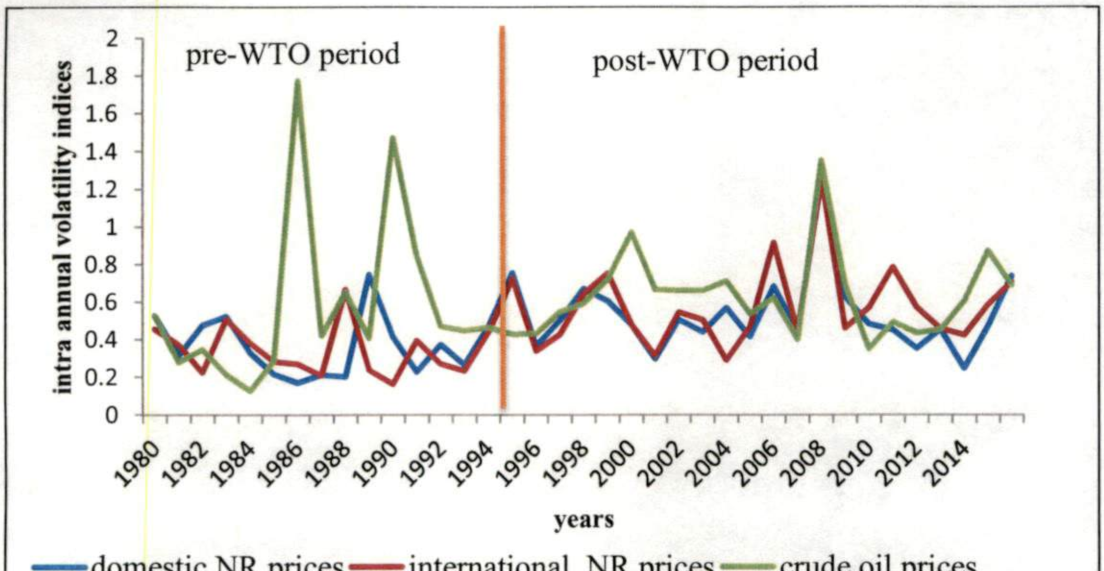

Figure 7: Graph representing intra annual volatility for prices of domestic NR, international NR and crude oil prices in rupees

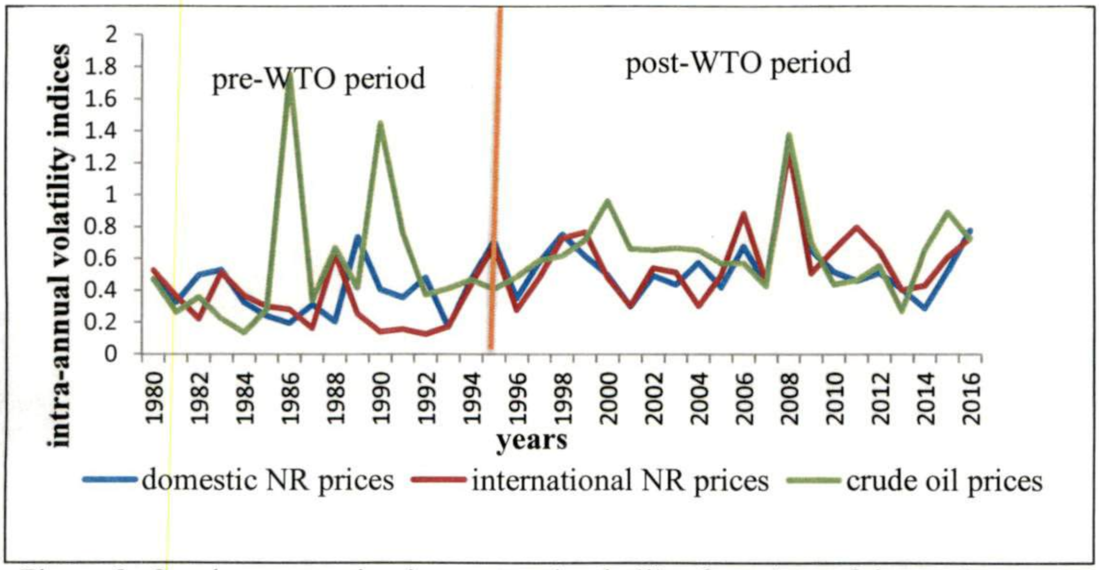

Figure 8: Graph representing intra annual volatility for prices of domestic NR, International NR and crude oil prices in US dollars

4.2.2. Inter-annual volatility

Inter annual volatility for monthly prices of domestic NR, international NR and crude oil were calculated to measure between the year dispersion.

The estimated inter annual volatility indices and their respective graphs are given in Table 4.4 and Figure 9. From the table, it could be observed that the volatility, in terms of rupees, ranged from Δ0 to 0.30, Δ0 to 0.35 and Δ0 to 0.37 for domestic NR, international NR and crude oil prices respectively. The range of inter annual volatility was higher in the post-WTO than the pre-WTO period for domestic NR and international NR price series. In the post-WTO period, 2008 to 09 exhibited the highest volatility while in the pre-WTO volatility was highest in 1984 to 87. Crude oil price series showed wide range of volatility in post-WTO than pre-WTO for the years 2008-09 to 2010-11 and 2012-13 to 2015-16.

The volatility of NR prices in US dollars is depicted in Table 4.4 and Figure 10. From the table, it could be observed that US dollar prices were showing higher volatility when compared to prices in rupees. It ranged from 0.0004 to 0.360, 0.0008 to 0.41 and Δ0 to 0.409 for domestic NR, international

NR and crude oil prices respectively. Inter-annual volatility was higher in post-WTO than pre-WTO periods for both domestic and international NR prices for the years 2008-11. Crude oil prices showed wide range of volatility in post-WTO than in pre-WTO for the year 2008-09 to 2010-11 and 2012-13 to 2015-16.

Sabu (2015) also analysed inter-annual and intra-annual volatility in black pepper prices. She reported that there was comparatively higher volatility in pre-WTO than in post-WTO periods for both inter-annual and intra-annual volatility in monthly prices of black pepper in terms of rupees and dollars for domestic and international markets.

Table.4.4 Inter-annual Volatility indices of monthly domestic NR, international NR and crude oil prices

Note: Figures denote range of volatility indices for each of the category of prices

Commodity/Price	Pre-WTO	Post-WTO	Overall period
In rupees			
Domestic NR prices	Δ0 - 0.105	Δ0 - 0.30	Δ0 - 0.30
International NR price	Δ0 - 0.09	Δ0 - 0.35	Δ0 - 0.35
Crude oil price	Δ0 - 0.37	Δ0 - 0.35	Δ0 - 0.37
In US dollars			
Domestic NR prices	0.0004 -0.10	0.002-0.36	0.0004 - 0.360
International NR price	0.0012 -0.09	0.001 -0.41	0.0008 - 0.41
Crude oil price	0.0003 -0.41	Δ0 - 0.41	Δ0 - 0.41

and Δ0 denotes very small value of zero

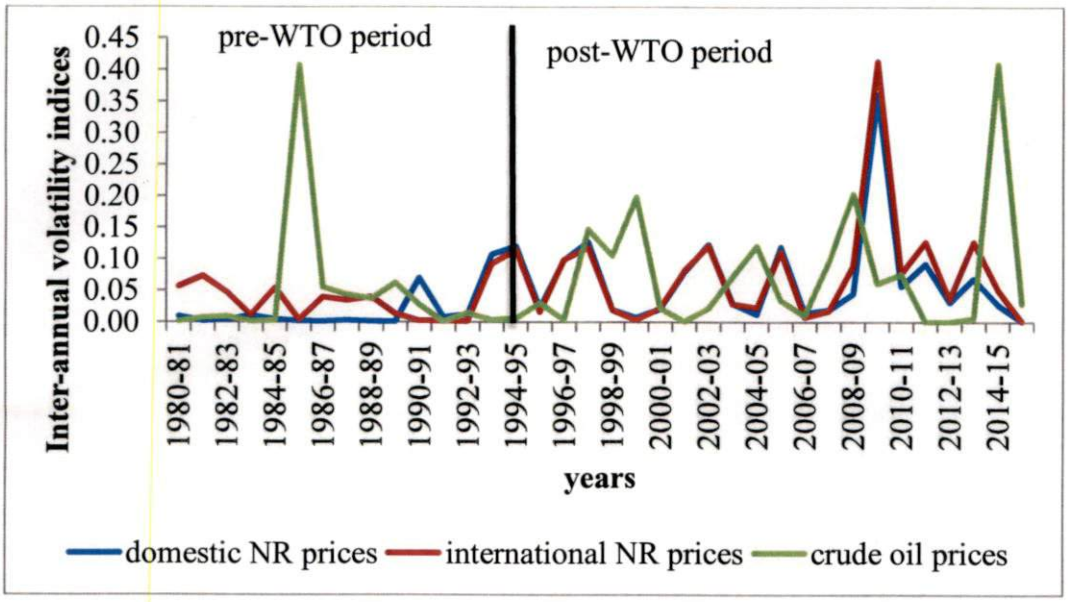

Figure 9: Graphs representing inter annual volatility for monthly domestic NR, international NR and crude oil prices in rupees.

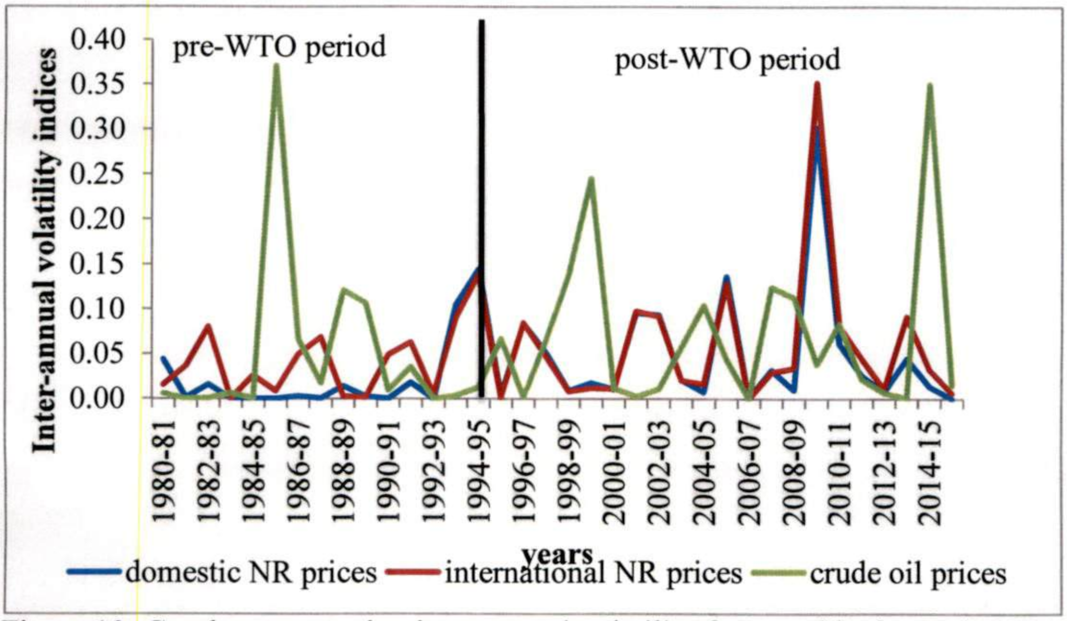

Figure 10: Graphs representing inter annual volatility for monthly domestic NR, international NR and crude oil prices in US dollars

4.2.3. Persistence of volatility –GARCH model

Volatility indices do not provide information on the persistence of volatility and hence GARCH models were fitted for which the volatility is summation of ARCH (α_i) and GARCH (β_i) terms. Among the various tried models, the results of best fit GARCH (1,1) model was fitted for both domestic and international NR prices in terms of rupee as well as US dollar.

The results of GARCH (1,1) for domestic NR price was given in Table 4.5. From the table, it could be observed that the volatility for domestic NR prices was persistent in pre-WTO and overall period while it was medium in post- WTO period. When the prices were considered in US dollars, the volatility showed persistence in post-WTO and overall periods, while in pre-WTO showed very high volatility.

The volatility estimates of international NR prices are presented in Table 4.6 and it could be observed that volatility for international NR prices in terms of rupees there was high volatility in pre-WTO and overall period and a moderate volatility in post-WTO period. With respect to US dollar prices, the volatility persisted in pre-WTO and overall periods, while in post-WTO period volatility was very high. The persistence may be due to the different factors like fluctuations in global markets and variation in demand and supply conditions, demand for raw materials and high prices of synthetic rubber (Anuja *et al.,* 2013). According to Chang *et al.* (2009), international rubber prices were not only exposed to changes in demand, but also to the assumptions about futures markets.

Table 4.5 Estimates of the GARCH models for domestic NR prices in rupees and US dollars

Details/Estimates	Pre-WTO	Post-WTO	Overall period
In rupees			
Constant	3.07	658479	660
Estimates of ARCH term (α_i)	1.20	0.68	0.74
Estimates of GARCH term (β_i)	-0.03	-0.18	0.46
($\alpha_i + \beta_i$)	1.17	0.50	1.20
Volatility	Persistence	Medium	Persistence
In US dollars			
Constant	0.003	-0.03	-0.04
Estimates of ARCH term (α_i)	0.83	0.75	0.64
Estimates of GARCH term (β_i)	0.11	0.50	0.51
($\alpha_i + \beta_i$)	0.94	1.25	1.15
Volatility	Very high	Persistence	Persistence

Table 4.6 Estimates of the GARCH models for international NR prices in terms of rupees and US dollars

Details/Estimates	Pre-WTO	Post-WTO	Overall period
In rupees			
Constant	60381.41	1791736	3323575
Estimates of ARCH term (α_i)	1.44	0.82	0.58
Estimates of GARCH term (β_i)	-0.55	-0.21	0.40
($\alpha_i + \beta_i$)	0.89	0.61	0.98
Volatility	Very high	Medium	Very high
In US dollars			
Constant	0.000317	0.009354	136413.1
Estimates of ARCH term (α_i)	1.12	0.92	0.94
Estimates of GARCH term (β_i)	-0.01	0.07	0.11
($\alpha_i + \beta_i$)	1.11	0.99	1.05
Volatility	Persistence	Very high	Persistence

4.2.4. Instability index

To estimate the instability in the monthly prices, Cuddy-Della Valle instability index was estimated.

4.2.4.1. Cuddy Della Valle Instability index

The results of the instability in monthly prices measured using Cuddy Della Valle instability index are presented in Table 4.7. For NR prices in rupees, the instability in the post-WTO period was almost double that of pre-WTO period and for the NR prices in US dollars, the instability was triple in the post-WTO as compared to the pre-WTO period. Prices in rupee showed more instability than prices in US dollars and this could be because of the instability in rupee-US dollar exchange rates.

A similar analysis was carried out from 2005-06 to 2011-12 for RSS-4 of NR prices (Anuja *et al.*, 2013). She reported that the instability in international market had substantial impact on the domestic market. Herath *et al.* (2013) reported that the country's economy will be affected badly by instability in prices, particularly foreign exchange rates and will affect mostly the overall development process of a country

Table 4.7: Cuddy Della Valle Instability index for rupees and US dollars

Market/ price	**Cuddy-Della Valle Instability index**		
	Pre-WTO	**Post-WTO**	**Overall period**
In rupees			
Domestic NR prices	20.92	45.85	65.25
International NR prices	36.86	47.94	72.51
Crude oil Price	24.49	52.63	80.75
In US dollars			
Domestic NR prices	14.88	42.29	39.14
International NR prices	13.90	44.75	47.83
Crude oil Price	22.40	45.53	53.37

4.3. Relationship between international and domestic prices

4.3.1. Cointegration analysis

The relationship between international and domestic prices of NR was investigated by cointegration analysis. Both pair-wise cointegration and multiple cointegration techniques were used to analyse the extent of co-movement of domestic NR prices, international NR prices and crude oil prices. The analysis was carried out for three period *viz.,* pre-WTO, post-WTO and overall periods in all the markets using monthly data. Separate co-integration tests were done for prices in rupee and US dollar terms.

The most important step considered in cointegration analysis is to test whether the series are integrated with the same order or not. In other words, the first step in cointegration analysis is to check the stationarity of the price series at levels by ADF test the results of which are presented in Table 4.8. At levels, the null hypothesis of non-stationary could be accepted, providing evidence that, all the three price series were non stationary, in all periods in rupee as well as US dollar terms. The null hypothesis was rejected concluding that each series was made stationary after first differencing and is integrated of order (1) in all the periods, in rupee as also US dollar terms (Table 4.8).

Cointegration analysis is carried out if the price series are integrated of the same order. As the ADF tests proved that all the three price series were integrated with order (1), cointegration analysis was carried out.

4.3.1.1. Pair wise cointegration

Pairwise cointegration was carried out for domestic NR and international NR prices; domestic NR prices and crude oil prices and international NR prices and crude oil prices for all the periods under consideration in both rupee and US dollar terms.

Results of pairwise cointegration done using Johansen method between domestic NR, international NR and crude oil prices in rupee are presented in Table 4.9. For testing cointegration between series, trace test and its probability

63

values were considered. Cointegration analysis was done at different lag lengths, which were decided by BIC criteria in VAR lag selection.

From the table, it is clearly evident that, for the post-WTO as also the overall periods, the null hypothesis i.e., no cointegration at r = 0 failed to be rejected and null hypothesis at r <= 1 was rejected at 5 percent level of significance for the pair-wise prices of domestic NR and international NR; domestic NR and crude oil and international NR and crude oil. By this, it was concluded that there was cointegration between these prices. Whereas, during the pre-WTO period, only the prices of domestic NR and international NR, domestic NR and Crude oil were integrated and there was no integration between international NR and crude oil prices.

From Table 4.10, it could be concluded that there was cointegration among all the prices in the post-WTO and overall periods when prices were considered in terms of US dollars. Null hypothesis of r = 0 failed to be rejected and r <= 1 was rejected at 5 per cent level of significance in overall as well as post-WTO periods. In the pre-WTO period, there was no cointegration between domestic NR and crude oil prices. As both null hypothesis r = 0 and r <= 1 failed to be rejected for international NR and crude oil prices in pre-WTO period in terms of dollars, it could be concluded that there was no cointegration.

4.3.1.2. Multiple cointegration

The results of the multiple cointegration analysis are presented in Table 4.11. The null hypothesis of no cointegration (r = 0) against the alternative hypothesis of presence of one or more cointegrating vector is rejected at 5% level of significance based on trace test and maximum eigen value except for the pre-WTO period for both rupees as well as dollars. This implies that cointegration exists between the domestic NR, international NR and crude oil prices.

The null hypothesis ($r \leq 1$) and ($r \leq 2$) against the alternative of the existence of two or three cointegrating vectors are not rejected by the both tests for prices in rupees and dollars. This implies that there was not more than one cointegration relationship between them in all periods.

Table 4.8 Results of ADF test at levels and first difference for prices of domestic NR, international NR and crude oil.

Pairs of Market/Prices	Pre-WTO			Post-WTO			Overall period		
	Tau	Rho	p value	Tau	Rho	p value	Tau	rho	p value
In rupees									
Levels									
Domestic NR prices	1.42	0.02	0.99	-1.15	0.01	0.69	-1.08	0.010	0.72
International NR prices	-2.00	-0.04	0.28	-1.28	-0.02	0.64	-1.11	-0.02	0.71
Crude oil prices	-0.77	0.00	0.82	-1.72	-0.02	0.42	-1.10	-0.01	0.72
First difference									
Domestic NR prices	-9.60	0.01	<0.001*	-12.59	0.01	<0.001*	-16.3	0.01	<0.001*
International NR prices	-9.49	-0.02	<0.001*	-8.98	0.00	<0.001*	-11.7	0.00	<0.001*
Crude oil prices	-8.16	0.00	<0.001*	-10.86	-0.01	<0.001*	-5.98	0.00	<0.001*
In US dollars									
Levels									
Domestic NR prices	-2.12	0.04	0.24	-1.47	0.01	0.55	-1.92	0.01	0.32
International NR prices	-3.00	0.08	0.34	-1.72	-0.04	0.42	-2.00	-0.03	0.29
Crude oil prices	-1.58	0.01	0.48	-2.02	-0.02	0.28	-1.53	0.00	0.51
First difference									
Domestic NR prices	-8.90	0.01	<0.001*	-12.04	0.01	<0.001*	-15.5	0.02	<0.001*
International NR prices	-10.3	0.08	<0.001*	-8.42	0.01	<0.001*	-11.0	0.01	<0.001*
Crude oil prices	-7.74	0.00	<0.001*	-10.19	-0.01	<0.001*	-9.89	0.01	<0.001*

Note: * Indicates significance at 5 per cent level

Table 4.9 Results of Pairwise cointegration by Johansen method between domestic NR, International NR and crude oil prices in rupee

Pairs of Markets/Prices	H_0	VAR Length	Eigen value	Trace test	p-value
Pre-WTO period					
Domestic and International NR prices	r=0 r<=1	2	0.11 0.07	34.05 12.93	<0.001* 0.12
Domestic NR and Crude oil prices	r=0 r<=1	2	0.07 0.01	15.89 2.16	0.04* 0.14
International NR and Crude oil prices	r=0 r<=1	3	0.05 0.03	24.77 8.66	<0.001* <0.001*
Post-WTO period					
Domestic and International NR prices	r=0 r<=1	3	0.04 0.00	33.15 1.10	<0.001* 0.29
Domestic NR and Crude oil prices	r=0 r<=1	3	0.11 0.00	33.15 1.10	<0.001* 0.29
International NR and Crude oil prices	r=0 r<=1	3	0.86 0.04	24.70 18.68	0.05* 0.15
Overall WTO period					
Domestic and International NR prices	r=0 r<=1	3	0.09 0.00	46.94 0.89	<0.001* 0.34
Domestic NR and Crude oil prices	r=0 r<=1	3	0.09 0.00	46.94 0.89	<0.001* 0.34
International NR and Crude oil prices	r=0 r<=1	3	0.03 0.00	18.99 1.69	<0.001* 0.19

Note: * indicates significance at 5 per cent level

Table 4.10 Results of Pairwise cointegration by Johansen method between prices of domestic NR, international NR and crude oil in dollar.

Pairs of Markets/Prices	H_0	VAR length	Eigen value	Trace test	p- value
Pre-WTO period					
Domestic and International NR prices	r=0	2	0.07	19.99	<0.001*
	r<=1		0.03	6.41	0.11
Domestic NR and Crude oil prices	r=0	2	0.08	18.97	<0.001*
	r<=1		0.15	2.84	0.09
International NR and Crude oil prices	r=0	2	0.08	20.63	0.03*
	r<=1		0.02	5.07	0.04*
Post-WTO period					
Domestic and International NR prices	r=0	4	0.01	39.87	<0.001*
	r<=1		0.00	1.85	0.21
Domestic NR and Crude oil prices	r=0	4	0.01	14.05	<0.001*
	r<=1		0.00	2.72	0.10
International NR and Crude oil prices	r=0	2	0.04	11.98	0.02*
	r<=1		0.00	0.01	0.93
Overall period					
Domestic and International NR prices	r=0	3	0.04	24.16	<0.001*
	r<=1		0.01	3.47	0.61
Domestic NR and Crude oil prices	r=0	2	0.03	18.26	0.02*
	r<=1		0.01	4.16	0.61
International NR and Crude oil prices	r=0	3	0.03	20.94	<0.001*
	r<=1		0.01	5.77	0.16

Note: *denotes significance at 5 per cent level.

Table 4.11 Results of multiple cointegration by Johansen method for prices of domestic NR, international NR and crude oil.

Period	Pairs of markets/Price	H_o for Trace test	Trace test statistic	Critical value	Max. Eigen value statistic	Critical value	Results
In rupees							
Pre-WTO	Domestic NR, International NR, crude oil prices	$r=0$ $r\leq1$ $r\leq2$	26.40 13.50 3.85	29.80 15.50 3.84	12.9 9.63 3.85	21.1 14.2 3.84	Fail to reject H_o Fail to reject H_o Reject H_o
Post WTO	Domestic NR, International NR, crude oil prices.	$r=0$ $r\leq1$ $r\leq2$	51.4 10.6 0.94	29.80 15.50 3.84	40.7 9.70 0.94	21.1 14.2 3.84	Reject H_o Fail to reject H_o Fail to reject H_o
Overall Period	Domestic NR, International NR, Crude oil prices.	$r=0$ $r\leq1$ $r\leq2$	68.9 14.9 0.76	29.80 15.50 3.84	53.9 14.2 0.76	21.1 14.2 3.84	Reject H_o Fail to reject H_o Fail to reject H_o
In US dollars							
Pre-WTO	Domestic NR, International NR, Crude oil prices.	$r=0$ $r\leq1$ $r\leq2$	22.9 8.26 3.50	29.8 15.50 3.84	14.6 4.76 3.50	21.1 14.2 3.84	Fail to reject H_o Fail to reject H_o Reject H_o
Post- WTO	Domestic NR, International NR, Crude oil prices.	$r=0$ $r\leq1$ $r\leq2$	51.4 11.8 1.86	29.80 15.50 3.84	39.6 9.93 1.86	21.1 14.2 3.84	Reject H_o Fail to reject H_o Fail to reject H_o
Overall period	Domestic NR, International NR, Crude oil prices.	$r=0$ $r\leq1$ $r\leq2$	35.6 12.6 3.19	29.80 15.50 3.84	22.9 9.37 3.19	21.1 14.2 3.84	Reject H_o Fail to reject H_o Fail to reject H_o

4.3.2. Vector Error Correction Model

Vector Error Correction Model (VECM) provides enough evidence on the long run relationship between the price variables under consideration. The fundamental requirements of VECM are cointegration and non-spurious regression. Cointegration analysis (Table 4.9 and 4.10) revealed that all the price series were cointegrated. Ordinary least squares (OLS) regression was carried out to find whether the price series shows spurious regression or not. OLS regression with levels given in Table 4.12. From the table, it is clearly evident that R^2 was higher than that of Durbin Watson (DW) statistic which confirmed the presence of spurious regression. So, OLS regression for first differences were carried out and given in Table 4.13. From the table, it could be concluded that there was no spurious regression at first differences as R^2 was less than DW statistic.

The results of the VECM attempted are presented in Table 4.14. Error term with one period lag was chosen by VAR lag selection criteria and it corrects the disequilibrium in variables. Error term was negative and significant at 5 per cent level of significance, indicating that there was long run equilibrium among the variables. The value of error term was -0.1087, meaning that 10.87 per cent of disequilibrium was getting adjusted every month by international NR and crude oil prices changes.

Short run equilibrium was indicated by the coefficients of the independent variables (Table 4.14). International NR prices had negative coefficient indicating that there was negative relationship on domestic NR prices and the coefficient value of -0.143 indicated that the domestic NR corrects its previous period at a speed of 14.3 per cent. Coefficient of crude oil prices (+0.0041) had positive relationship with domestic rubber and indicating that it corrects its previous period by 0.41 per cent. Joseph (2004) also concluded that there was long run and short run elasticity in rubber and also reported that domestic market price is also getting influenced by domestic supply conditions.

A similar relationship was obtained between electricity consumption and foreign aid in Nepal (Dhungel, 2014). He estimated that at a speed of 33.6% annually, system corrects its disequilibrium past period to reach at the steady state.

Table 4.12 Results of OLS parameter estimation at levels for domestic NR price

	Coefficient	Std. Error	t-value	p-value
Const	264.74	56.23	4.71	<0.001*
International NR prices	0.84	0.02	48.70	<0.001*
Crude oil prices	0.01	0.00	9.79	<0.001*
R^2	0.97			
Adjusted R^2	0.95			
DW statistic	0.33			

Note:* indicates significance at 5 per cent level

Table 4.13 Results of OLS parameter estimation at first difference for domestic NR price

	Coefficient	Std.Error	t-value	p-value
Const	40.08	24.80	1.62	0.11
d_international NR price _1	−0.143	0.05	−2.82	<0.001*
d_crudeoil price_1	0.0041	0.002	2.89	<0.001*
EC1 (U_{t-1})	−0.1087	0.03	−3.67	<0.001*
R^2	0.11			
Adjusted R^2	0.10			
DW statistic	1.89			

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Table 4.14 Results of Short run and long run equilibrium for domestic NR prices with respect to international NR and crude oil prices

Equilibrium	d(International NR price)		d(crude oil price)		Error term(U_{t-1})	
	Coefficient	Prob	Coefficient	Prob	Coefficient	Prob
Short run	−0.143	<0.001*	0.002	<0.001*		
Long run					−0.11	<0.001*

4.3.3. Price transmission

Cointegration test revealed that the price series in all the periods were integrated with one another, but the information about the direction of flow of information among these markets was not known. For that purpose, Granger causality tests were conducted.

To test for causality among all the three price series, Granger causality test was conducted separately for prices in rupee and US dollar terms in pre-WTO and post-WTO periods among three price series. When the prices were considered in terms of rupee (Table 4.15), cointegration between prices of domestic NR and international NR prices and domestic NR price and crude oil price was proved in pre WTO period. Among these prices, the direction of flow was supported by causality tests by rejecting the null hypothesis and it could be concluded that domestic NR price Granger caused crude oil price and international NR price granger caused the domestic NR price. But when the prices were considered in terms of dollars (Table 4.16), cointegration was found between for domestic NR and international NR prices and international NR and crude oil prices. The direction of flow among these series based on the causality tests was that the crude oil price caused the international NR prices and international NR price caused the domestic NR prices.

In post-WTO and overall periods, cointergation was proved among all the price series and the causality test also gave evidence that NR that both international NR price and domestic NR price caused the crude oil price whereas domestic NR price was caused by international NR price.

A similar analysis was carried out for energy consumption and economic growth in eight European countries (Theodoridis, 2013). He observed unidirectional causal relationship between European countries except for England where bidirectional causality was found.

Table 4.15 Results of Granger Causality test for monthly prices of domestic NR in rupee

Null hypothesis	**Pre WTO**		**Post WTO**		**Overall period**	
	F Stat	**Prob.**	**F Stat**	**Prob.**	**F Stat**	**Prob.**
Domestic NR prices does not granger cause International NR prices	2.45	0.12	2.07	0.15	2.36	0.13
Domestic NR prices does not granger cause Crude oil prices	3.10	0.08***	11.68	<0.001*	20.50	<0.001*
Crude oil prices does not granger cause International NR prices	1.37	0.24	0.73	0.40	1.10	0.30
International NR prices does not granger cause on Domestic NR prices	9.65	<0.001*	6.79	0.01*	12.83	<0.001*
Crude oil prices does not granger cause Domestic NR prices	0.02	0.90	1.04	0.31	1.38	0.24
International NR prices does not granger cause Crude oil prices	2.56	0.11	13.39	<0.001*	24.05	<0.001*

Note: * denotes significance at 5 percent level and ***denotes significance at 10 percent level.

Table 4.16 Results of Granger Causality test for monthly prices of domestic NR in US dollar

Null hypothesis	Pre WTO		Post WTO		Overall period	
	F Stat	Prob.	F Stat	Prob.	F Stat	Prob.
Domestic NR prices does not granger cause on International NR prices	0.97	0.33	0.94	0.34	0.02	0.87
Domestic NR prices does not granger cause on Crude oil prices	2.31	0.13	6.16	0.01*	6.85	0.01*
Crude oil prices does not granger cause on International NR prices	5.16	0.02*	0.20	0.65	0.31	0.58
International NR prices does not granger cause on Domestic NR prices	4.52	0.03*	8.14	<0.001*	9.11	<0.001*
Crude oil prices does not granger cause on Domestic NR prices	1.36	0.26	0.05	0.83	0.02	0.88
International NR prices does not granger cause on Crude oil prices	1.11	0.30	8.99	<0.001*	14.5	<0.001*

Note: *denotes significance at 5 per cent level

4.4. Factors affecting NR prices

There are many factors affecting the prices of domestic NR. Some of the major factors are discussed below.

4.4.1. General factors affecting domestic NR prices

4.4.1.1. Synthetic rubber production and crude oil prices

Synthetic rubber (SR) is the good substitute for NR and crude oil is the major gradient for production of SR. The production of SR or crude oil prices directly affects the prices of the NR. If the price of crude oil decreases, it leads to high production of SR, which in turn decreases prices of NR. Figure 11, gives clear idea about NR price, crude oil price and SR production. It reveals that NR price and crude oil prices are moving in same direction whereas, it is vice versa for SR production.

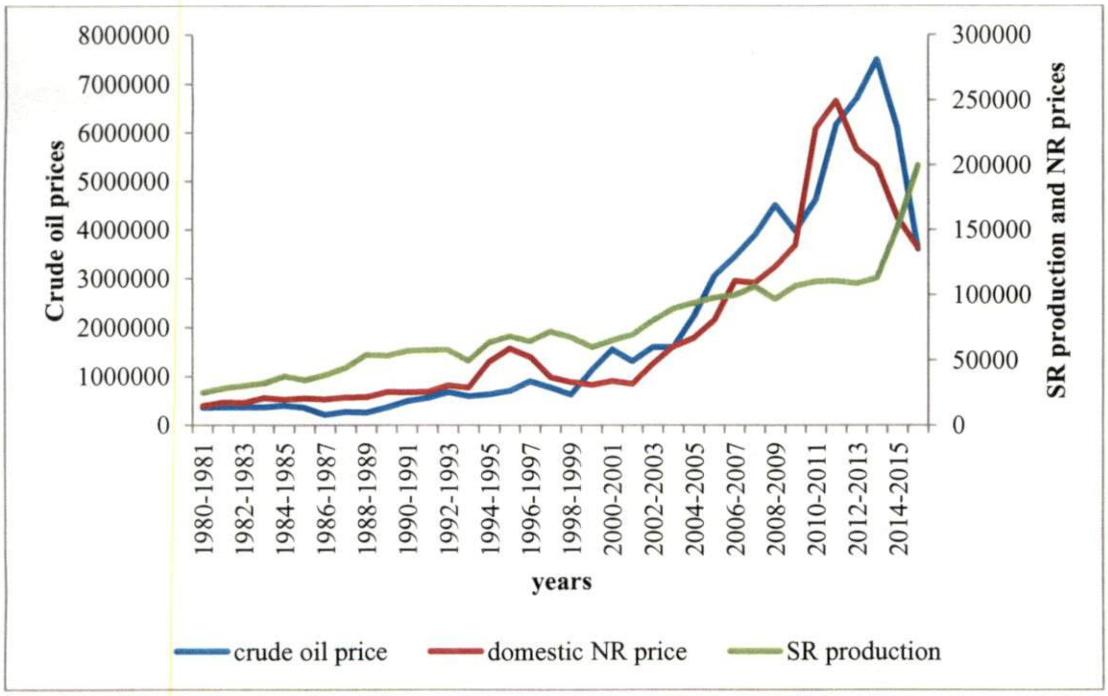

Figure 11: Graph depicting Crude oil price, NR price and SR production

4.4.1.2. Major export markets and demand and supply in international markets

Thailand, Malaysia and Indonesia are the major NR producing countries. These countries have control over demand and supply. Import of NR by US and Japan will have a greater influence on the world prices.

4.4.1.3. Natural factors

Seasonal and climatic changes are the major factors affecting NR prices. As discussed in the earlier section 4.1.2, the peak season for harvesting of NR in India is from October to January, while the slack period is during monsoon. The prices exhibit an inverse relationship with production of NR.

Climatic conditions for growing NR are annual average temperature of 30°C and rainfall of above 2000 mm. where these conditions are not met, the latex formation will be affected which in turn have impact on prices.

4.4.1.4. The international market transaction quotes

As NR is an internationally traded commodity, transaction between different countries and markets will affect the domestic price. Tokyo Commodity Exchange (TOCOM), Japan's Kobe Rubber Exchange (KOBE), Singapore RAS Commodity Exchange and Kuala Lumpur Commodity Exchange (KLCE) are the available major exchanges taking up futures trading in NR. Among them, Singapore and Tokyo are the major markets which reflect world NR prices.

4.4.1.5. Development of the rubber industry such as tyres and related automotive industry

Tyre and automobile industry are the major industries which utilises NR. The demand for NR by these industries directly affects the rubber market. Automobile industry is the biggest consumer of NR, so the development in automobile industry and related policies also affect the demand for tyres which in turn influence the demand for NR.

4.4.1.6. Influence of exchange rates

The currency of exporting countries and NR prices share an inverse relationship. The exchange rates between India and exporting countries are also a factor for fall in rubber prices. As depicted in the Figure 12, when dollar gains strength against rupee rubber prices, starts declining and vice versa.

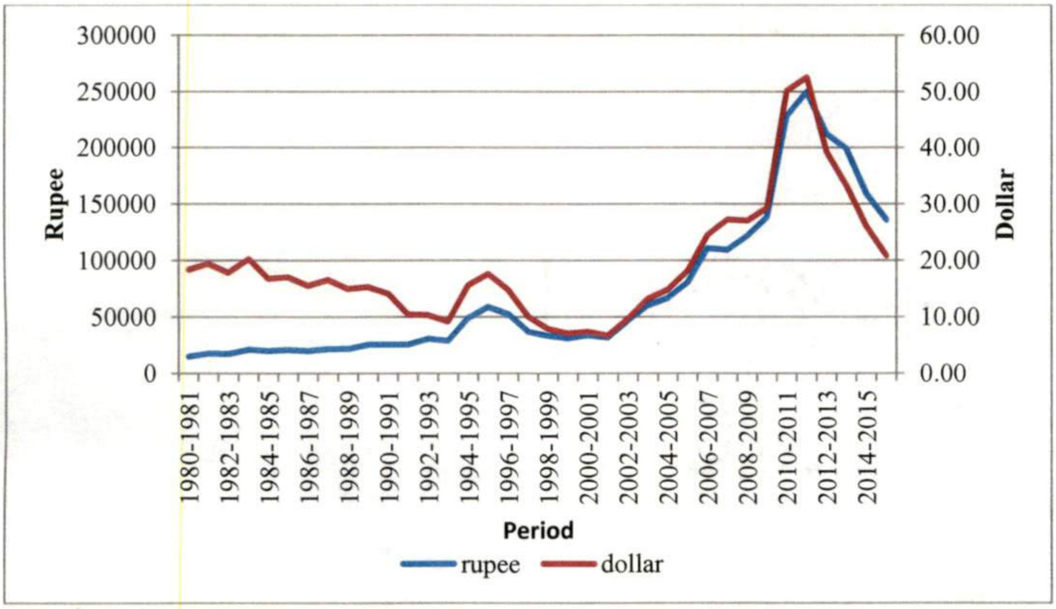

Figure 12: Graph representing difference between price of domestic NR in rupee and US dollar

4.4.2. Factors affecting domestic NR prices in pre-WTO and post-WTO periods

Domestic NR prices directly or indirectly depend upon many factors like production and consumption of NR, international NR prices, crude oil prices, import unit value of NR and production and consumption of SR. The important factors affecting the domestic NR prices were identified by step wise regression method given in Table 4.17. From the table, it could be observed that the international NR price affected domestic NR price in pre-WTO period while in post-WTO period, both international price and SR consumption affected the domestic NR price.

Table 4.17 Results of step wise regression for factors affecting NR prices in pre-WTO and post-WTO period

	Coefficient	**Std. Error**	**t value**	**Sig**
Pre-WTO period				
Model				
Constant	996.57	1322.22	7.5	<0.001*
International NR prices	0.71	0.06	12.08	<0.001*
Post-WTO period				
Model I				
Constant	-123.92	393.01	-0.03	<0.001*
International NR price	1.02	0.03	31.61	<0.001*
Model II				
Constant	1224	2899.8	-4.220	<0.001*
International NR prices	0.871	0.030	29.36	<0.001*
SR Consumption	0.09	0.02	6.50	<0.001*

Note: * indicates significance at 5 per cent level

Model summary statistics for pre-WTO and post-WTO period is given in Table 4.18. It gives an additional evidence for the results obtained above. R^2 and adjusted R^2 were very high in both the periods, indicating that the independent variables were appropriate for the model, as they were explaining much of the variation on the dependent variable, domestic NR price.

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Table 4.18 Model summary Statistics for Step wise regression for pre-WTO and post-WTO period

Model	R	R^2	Adjusted R^2	Std. Error
Pre-WTO period				
Model I	0.96[a]	0.92	0.91	2423.20
Post-WTO period				
Model I	0.991[a]	0.98	0.98	9888.59
Model II	0.997[b]	0.99	0.99	5553.62

a. international NR prices
b. international NR prices and SR consumption

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4.5. Forecasting models

The price forecast of domestic NR was attempted through methods like stepwise linear regression method, ARIMA and SARIMA. The results are as follows.

4.5.1. Step wise linear regression method

Prediction of future prices of domestic NR was done by using step wise regression method period with domestic NR price as dependent variable and production and consumption of NR, international NR prices, crude oil prices, import unit value of NR and production and consumption of SR. Before predicting the prices for the year 2011-12 to 2015-16 was taken as validation period.

Stepwise regression model was carried out for the validation (Table 4.19). From the table, it could be observed that among many independent variables considered for the model, only international NR prices and import unit values were found highly correlated and significant with domestic NR prices. The rest of the independent variables were excluded from regression. Model summary statistic (Table 4.20) indicates that R^2 and adjusted R^2 were high for both models. Tolerance level and Variance Inflation Factor (VIF) were 0.558 and 1.79 respectively proved that there was no collinearity among the variables. DW statistic was 1.47 which also indicated that there was weak autocorrelation among the variables.

Table 4.19 Step wise regression method for Validation period

Model	Coefficient	Std.error	t-value	Sig.
Model I				
Constant	4382.10	1401.25	3.127	0.04*
International NR price	0.94	0.20	46.883	<0.001*
Model II				
Constant	2929.52	1284.39	2.28	0.03*
International NR price	0.85	0.03	27.36	<0.001*
Import value	0.12	0.04	3.32	<0.001*

Table 4.20 Summary statistics for stepwise regression model for validation period of domestic NR prices

Model	R^2	Adjusted R^2	Collinearity Statistic		DW statistic	Avg.Cooks Distance
			Tolerance	VIF		
1	0.98[a]	0.98	0.56	1.79	1.47	0.16
2	0.99[b]	0.99	0.56	1.79		

a. international NR prices

b. international NR prices and import unit value

The prediction equation from step wise regression given is obtained as

Domestic NR price = 2929.52 + 0.85 * international NR price + 0.12 * import unit value.

By using the above formula, prediction was done for next five years, i.e., 2011-12 to 2015-16 and the result were as given in Table 4.21 along with their standard errors. From Figure 13, it could be observed that the predicted values were almost equal to original values.

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Table 4.21 Validation for domestic NR prices using Step wise regression method

Year	Original Values	Predicted Values	Std. Error
2011-12	249658	240482.7	9575.25
2012-13	212178	206584	5594.04
2013-14	199229	204117.8	-4888.83
2014-15	159086	170481.1	-11395.1
2015-16	135676	155448.4	-9772.4

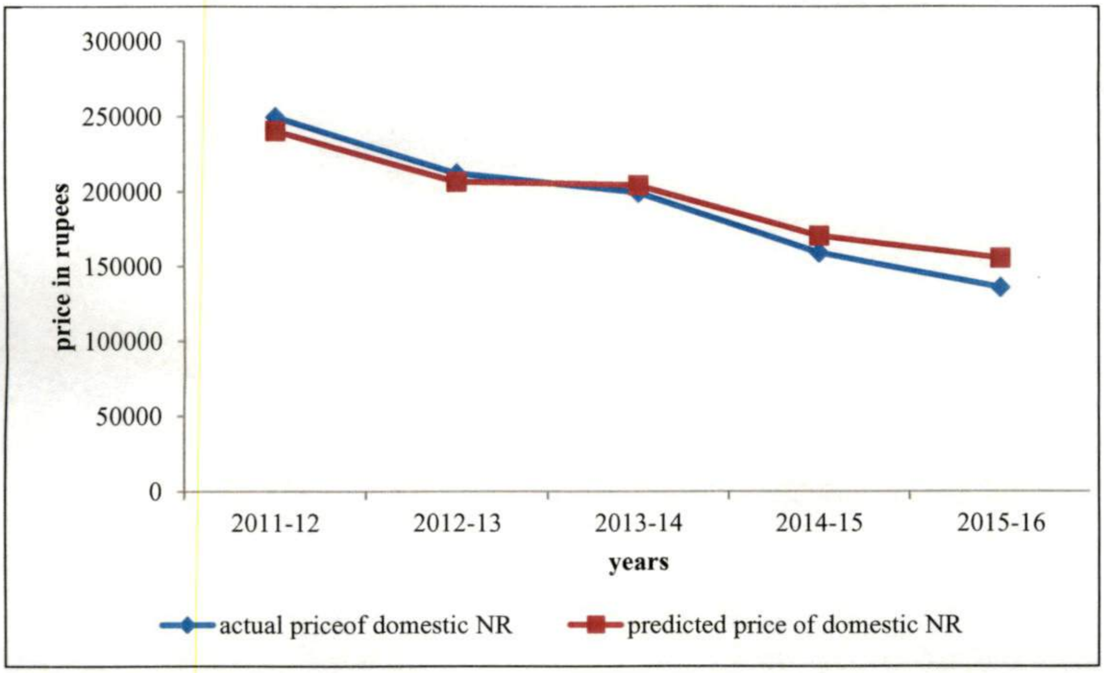

Figure 13: Graph representing the original values and predicted values for validation period obtained by Stepwise regression method

The prediction of domestic NR can be done if the international NR price and import unit value figures are known in advance.

4.5.2. ARIMA model for domestic NR rubber prices

The time plot of domestic rubber prices indicates the non-stationary of the data. ACF and PACF are provided in the Table 4.22. It indicates the significance of ACF and PACF values for domestic NR prices.

The ACF and PACF plots for domestic NR prices are depicted in Figure 14. It could be observed that in the ACF plot, there was a gradual decrease in the spikes which indicates the non-stationarity of the time series data on price. PACF plot also showed significant spikes at lag 1 and 2.

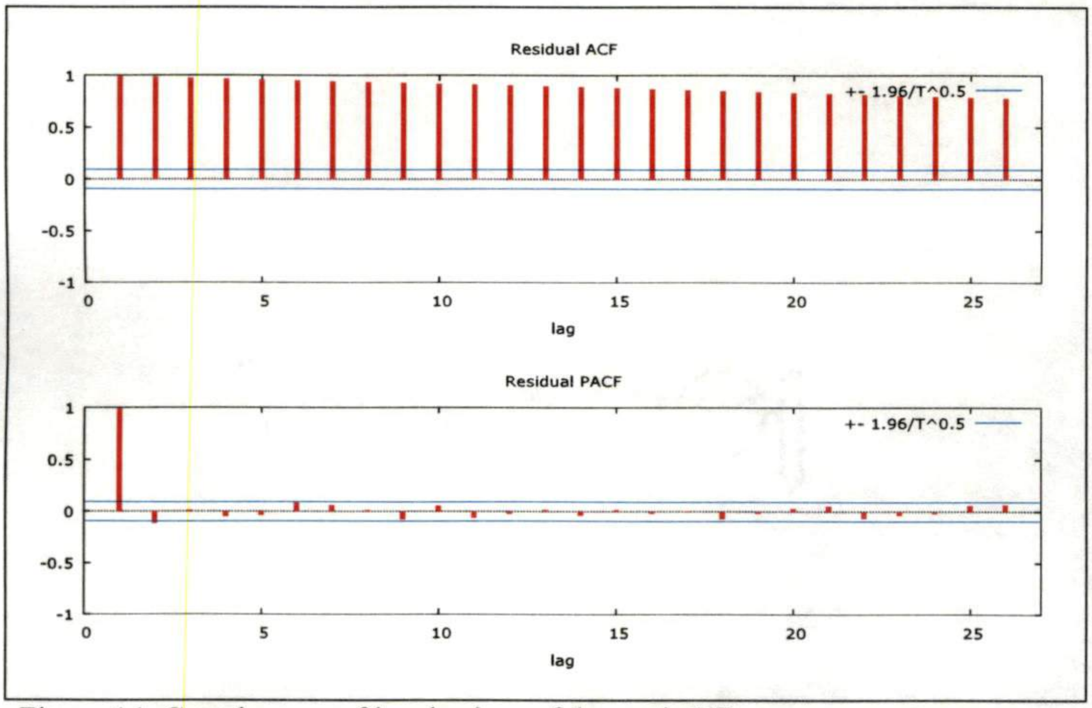

Figure 14: Correlogram of level prices of domestic NR

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Table 4.22 ACF and PACF values for correlogram for domestic NR price

LAG	ACF	PACF	Q-stat.	p-value
1	0.9926	0.9926	440.42	<0.001*
2	0.9836	-0.1122	873.90	<0.001*
3	0.9748	0.0163	1300.55	<0.001*
4	0.9654	-0.0478	1719.91	<0.001*
5	0.9554	-0.0342	2131.69	<0.001*
6	0.9468	0.0967	2536.94	<0.001*
7	0.9394	0.0582	2936.78	<0.001*
8	0.9323	0.0104	3331.51	<0.001*
9	0.9244	-0.0738	3720.52	<0.001*
10	0.9173	0.056	4104.45	<0.001*
11	0.9096	-0.0585	4482.86	<0.001*
12	0.9012	-0.0224	4855.12	<0.001*
13	0.8929	0.014	5221.40	<0.001*
14	0.8843	-0.0365	5581.50	<0.001*
15	0.8757	0.0136	5935.51	<0.001*
16	0.8671	-0.0146	6283.37	<0.001*
17	0.8587	0.0068	6625.24	<0.001*
18	0.8495	-0.0694	6960.77	<0.001*
19	0.8400	-0.0173	7289.50	<0.001*
20	0.8308	0.027	7611.83	<0.001*
21	0.8226	0.0517	7928.79	<0.001*
22	0.8135	-0.0628	8239.71	<0.001*
23	0.8041	-0.0308	8543.92	<0.001*
24	0.7946	-0.016	8840.96	<0.001*
25	0.7861	0.0587	9132.95	<0.001*
26	0.7783	0.0661	9419.93	<0.001*

$p<0.05$ indicates significance of autocorrelation

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4.5.2.1. Identification of ARIMA model

The chief tools in the identification step are ACF and PACF and resulting correlograms. From Figure 14, it is clear that the data was non-stationary. The stationarity of the data was assessed using ADF test. ADF test was conducted at both levels and first differences for prices of domestic NR. The significance of the ADF test statistic given in Table 4.18 confirmed the necessity of the first differencing and the correlogram of the first differenced domestic NR prices is given in Figure 15.

Table 4.23 ADF test and lagged difference for domestic NR price

	ADF test statistic (Tau statistic)	Probability	Lagged differences
Zero difference	-0.06	0.66	5.94
First difference	-3.48	0.0004	2.71

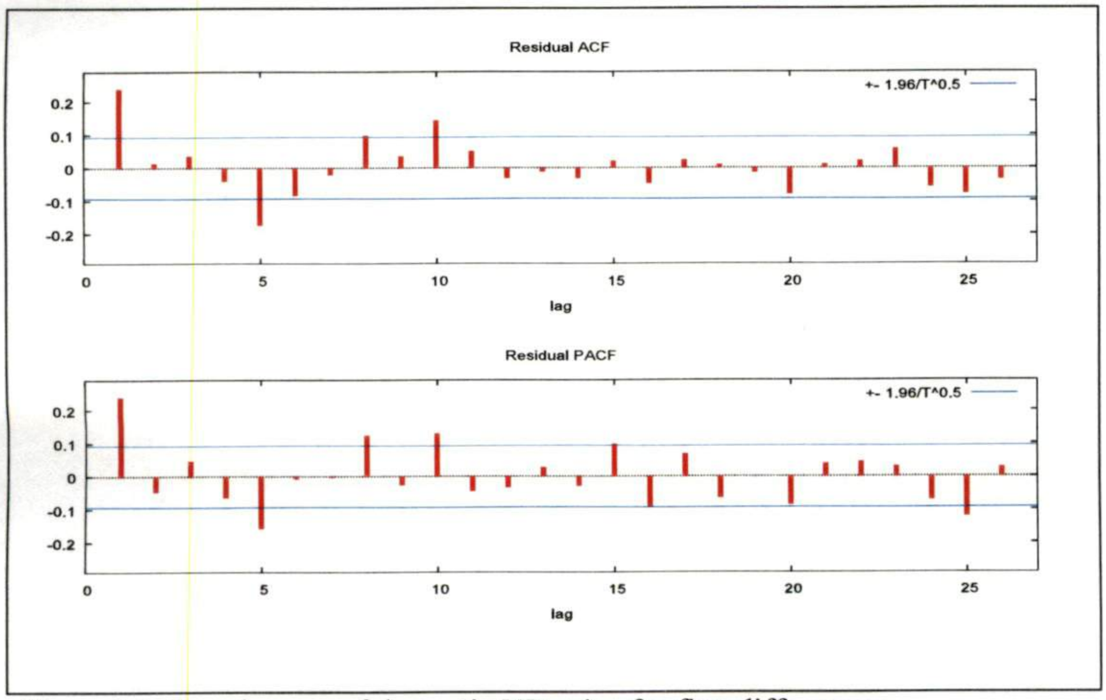

Figure 15: Correlogram of domestic NR price for first differences

4.5.2.2. Estimation of ARIMA Model

Different ARIMA models have been tried for estimating best model for forecasting analysis out of which ARIMA (1,1,0), ARIMA (2,1,2), ARIMA (3,1,4) and ARIMA(4,1,4) were found to be best.

4.5.2.3. Diagnostic checking for ARIMA models

From among the several ARIMA models tried, ARIMA (4,1,4) was identified as the best model for forecasting domestic NR prices. This model was proved best by the diagnostic checking using Ljung-box Q statistic, Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC) showed in Table 4.24. The lesser the value of the criterion, the better the model was considered fit for forecasting.

Table 4.24 Diagnostic checking for model parameters of domestic NR prices

Diagnostic checking				
Models	**BIC**	**AIC**	**Ljungbox Q-statistic**	**p-value**
ARIMA(1,1,0)	6816.9	6804.6	31.50	<0.001*
ARIMA(2,1,2)	6833.5	6808.9	30.85	<0.001*
ARIMA(3,1,4)	6832.2	6795.3	22.58	<0.001*
ARIMA(4,1,4)	6814.7	6773.8	7.56	0.1092

From Table 4.24, it could be concluded that ARIMA (4,1,4) is the best model among all the models tried.

Thus, ARIMA (4,1,4) model for domestic NR price is

$$(1-\phi_1B-\phi_2B^2-\phi_3B^3-\phi_4B^4)\ (1-B)\ y_t = (1-\theta_1B-\theta_2 B^2-\theta_3B^3-\theta_4B^4)\ \varepsilon_t$$

$$(1-0.37B-0.25B^2-0.47B^3-0.63B^4)\ (1-B)\ y_t = (1-0.65B-0.14B^2-0.53B^3-0.84B^4)\ \varepsilon_t$$

The parameters estimates for ARIMA (4,1,4) are given in Table 4.25.

Table 4.25 Parameter estimates of ARIMA (4,1,4) model for domestic NR prices

Parameters	Coefficient	Std. Error	Z	p-value
Non-seasonal difference	1			
phi_1	0.37	0.07	5.40	<0.001*
phi_2	0.25	0.07	3.47	<0.001*
phi_3	0.47	0.09	5.20	<0.001*
phi_4	0.63	0.06	9.61	<0.001*
theta_1	0.65	0.06	11.09	<0.001*
theta_2	0.14	0.06	2.18	<0.001*
theta_3	0.53	0.08	6.63	<0.001*
theta_4	0.84	0.06	14	<0.001*

Note:* indicates significance at 5 per cent level

The model fit statistics obtained for the above model are given in Table 4.26

Table 4.26 Model fit statistics of ARIMA (4,1,4) model for domestic NR prices

Model fit Statistics					
ARIMA(4,1,4)	**R^2**	**RMSE**	**MAE**	**MAPE**	**Runs test**
	0.94	493.75	276.73	4.33	p=0.33

The R^2 value indicates that the ARIMA (4,1,4) model explains 94 per cent of the variation in the domestic NR price series. Residual ACF and PACF plots are presented in Figure 16. From the graph, it could be observed that majority of the spikes in ACF and PACF plots were within the critical values. This proves additionally, the adequacy of ARIMA (4, 1,4) model for domestic NR prices.

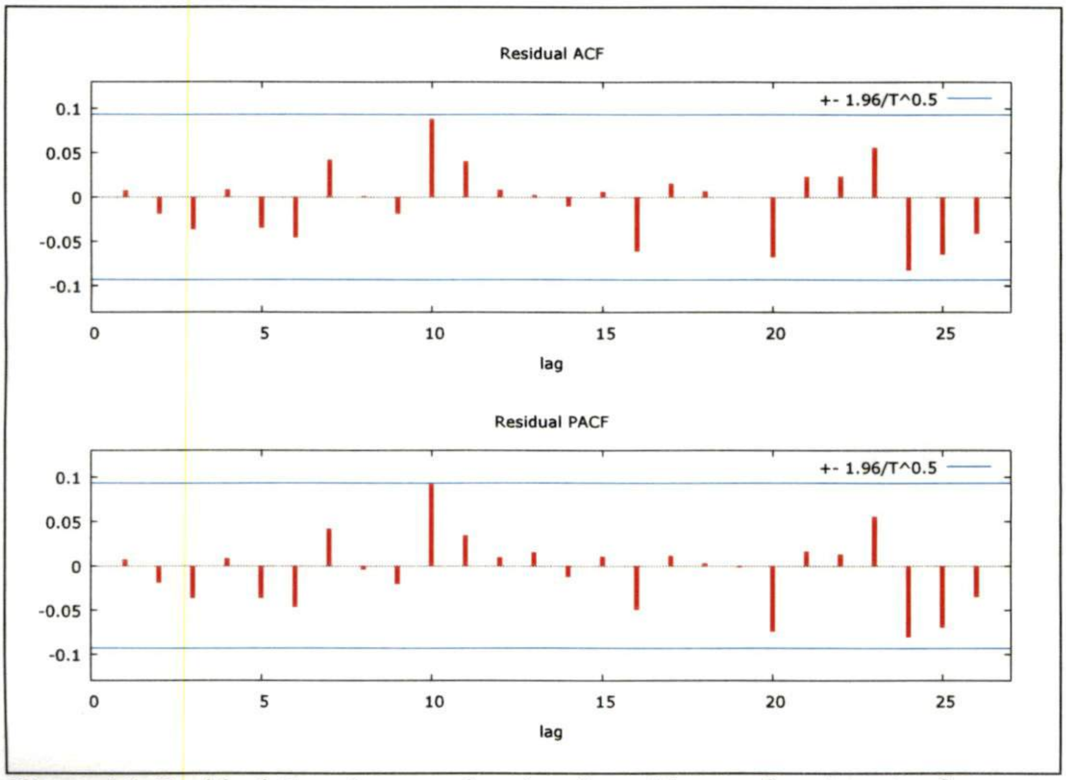

Figure 16: Residual Correlogram showing the evidence of stationarity for ARIMA (4,1,4) model

4.5.2.4. Validation for domestic NR price using ARIMA (4,1,4) model

The validation period for the above model identified was taken as six months. The forecasts were generated for the validation period i.e., from July 2016 to December 2016, and it was found that all the observations are within the confidence limits as shown in Table 4.27 and given in Figure 17. By this, it could be proved that the model ARIMA (4,1,4) identified was realistic.

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Table 4.27 Validation for domestic NR prices using ARIMA (4,1,4) model

Year & month	Actual values	Predicted values	Difference	Std. Error	Confidence limits (95%)
2016:07	14177	13525.66	651.34	489.04	12567.15-14484.16
2016:08	13850	13348.05	501.95	791.60	11796.5-14899.57
2016:09	12142	13047.11	-905.11	1008.33	11070.81-15023.41
2016:10	11692	12930.35	-1238.35	1221.342	10536.57-15324.14
2016:11	12214	13959.98	-1745.98	1410.49	10195.46-1572.50
2016:12	13370	13277.09	92.91	1544.79	10199.36-16254.83

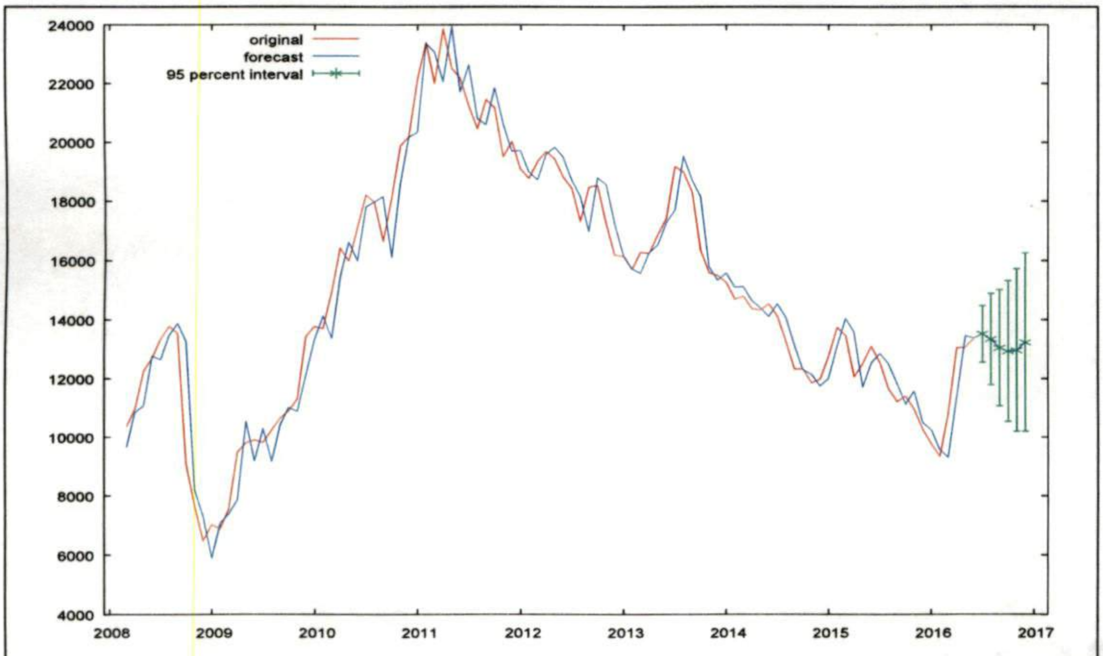

Figure 17: Graph representing the forecast of validation period of domestic NR by using ARIMA (4,1,4) model

Forecasting of domestic NR prices using ARIMA (4,1,4) model

The predicted prices in the validation period tallied approximately with the actual prices. The prediction period was taken as the subsequent six months period of the validation period. The predicted values are given in Table 4.28 and Figure 18 shows the prediction for 6 months.

Table 4.28 Forecast values for domestic NR prices using ARIMA (4,1,4) model

Year/month	**Predicted value**	**Std. Error**	**95% Confidence limit**
2017:01	13891.59	493.737	12923.88 - 14859.29
2017:02	14186.69	803.569	12611.73 - 15761.66
2017:03	14345.6	1024.616	12337.39 - 16353.81
2017:04	14271.89	1240.907	11839.76 - 16704.03
2017:05	13935.64	1432.827	11127.35 - 16743.93
2017:06	13844.32	1568.093	10770.92 - 16917.73

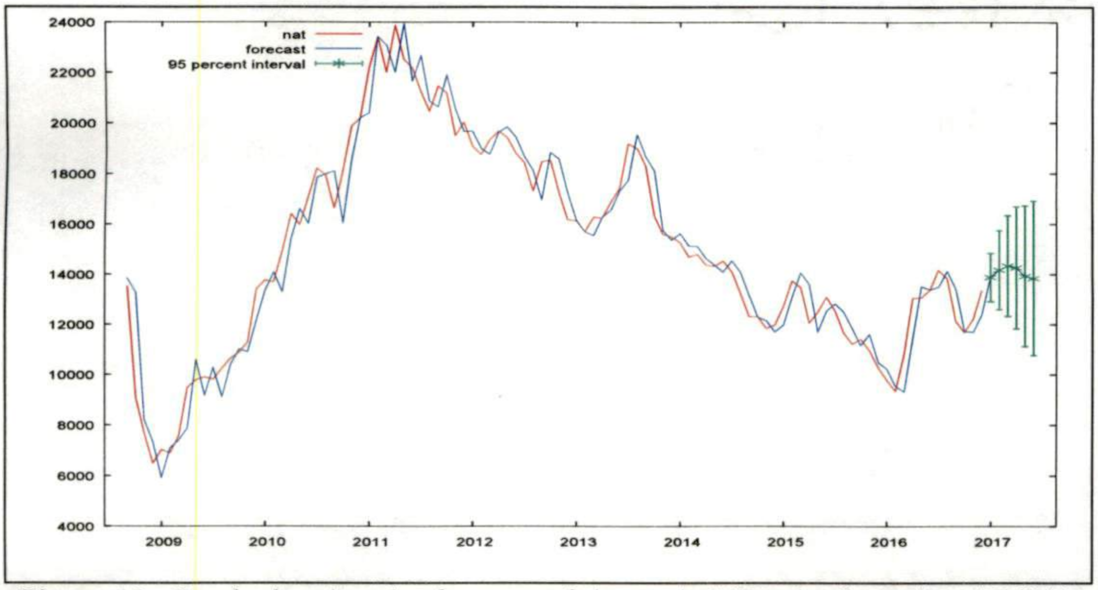

Figure 18: Graph showing the forecast of domestic NR price by using ARIMA (4,1,4) model

These findings were in concordance with the forecasts made for Malaysian Natural Rubber (SMR-20) by AyeAye and Thambiah (2014). They tried ARIMA models and ARIMA (1,1,1) model was identified as the best based on several accuracy measures like RMSE, MAE, U-Theil's, AIC and BIC criteria.

4.5.3. SARIMA Model

As the production of domestic NR is seasonal, seasonal ARIMA i.e., SARIMA was also tried for forecasting the NR prices.

4.5.3.1. Estimation of SARIMA model

Different SARIMA models have been tried for estimating best model for analysis. Out of which SARIMA $(1,1,0)(1,0,1)_{12}$, SARIMA $(2,1,2)(1,1,0)_{12}$, SARIMA $(3,1,3)(1,0,1)_{12}$ and SARIMA$(4,1,4)(1,0,1)_{12}$ found to be best.

4.5.3.2. Diagnostic checking for estimated SARIMA models

From among the several SARIMA models tried, SARIMA $(4,1,4)(1,0,1)_{12}$ was identified as the best model for domestic NR price. This model was proved best by the following diagnostic checking like ljung-box Q statistic, AIC and BIC showed in Table 4.29. The lesser value of the criterion, the better the model was considered fit for forecasting.

Table 4.29 Diagnostic checking for model parameters of domestic NR price for SARIMA model

Diagnostic checking				
Models	BIC	AIC	Ljung box Q-statistic	p-value
SARIMA$(1,1,0)(1,0,1)_{12}$	6826.89	6806.42	30.37	<0.001*
SARIMA$(2,1,2)(1,1,0)_{12}$	6824.54	6796.07	32.86	<0.001*
SARIMA$(3,1,3)(1,0,1)_{12}$	6840.69	6799.76	17.60	<0.001*
SARIMA$(4,1,4)(1,0,1)_{12}$	6826.15	6777.03	7.92	0.28

From the table, it could be concluded that SARIMA $(4,1,4)(1,0,1)_{12}$ was the best model among all the SARIMA models estimated. Even though, the AIC and BIC values were comparatively lower in the model SARIMA $(2,1,2)(1,1,0)_{12}$, the error structures were not within the limits. Hence, SARIMA (4,1,4)

$(1,0,1)_{12}$ was opted as the best fit model among all the SARIMA models attempted.

Thus, SARIMA (4,1,4) $(1,0,1)_{12}$ model for domestic NR price is

$(1-\phi_1B-\phi_2B^2-\phi_3B^3-\phi_4B^4)$ (1-B) $(1-\Phi_1B^{12})$ y_t = $(1-\theta_1B-\theta_2-B^2-\theta_3B^3-\theta_4B^4)$ + $(1-\Theta_1B^{12})\varepsilon_t$

$(1-0.37B-0.26B^2-0.44B^3-0.62B^4)$ (1-B) $(1-0.58B^{12})$ y_t = $(1-0.66B-0.15\ B^2-0.51B^3-0.83B^4)$ + $(1-0.62\ B^{12})\varepsilon_t$

The parameters estimates for SARIMA (4,1,4) $(1,0,1)_{12}$ are given in Table 4.30

Table 4.30 Parameter estimates of SARIMA (4,1,4) $(1,0,1)_{12}$ model

Parameters	**Coefficient**	**Std. Error**	**Z**	**p-value**
Non-seasonal difference	1			
phi_1 (ϕ_1)	−0.37	0.07	−5.39	<0.001*
phi_2 (ϕ_2)	0.26	0.08	3.08	<0.001*
phi_3 (ϕ_3)	−0.44	0.10	−4.10	<0.001*
phi_4 (ϕ_4)	−0.62	0.07	−9.26	<0.001*
Phi_1 (Φ_1)	0.58	0.31	1.89	0.04*
theta_1 (θ_1)	0.66	0.06	10.91	<0.0001*
theta_2 (θ_2)	−0.15	0.07	−2.09	0.03*
theta_3 (θ_3)	0.51	0.10	4.84	<0.001*
theta_4 (θ_4)	0.83	0.07	11.64	<0.001*
Theta_1 (Θ_1)	−0.62	0.30	−2.10	0.03*

Note:* significance at 5 per cent level.

The model fit statistics obtained for the above model are given in Table 4.31.

Table 4.31 Model fit statistics of SARIMA (4,1,4) $(1,0,1)_{12}$ model for domestic NR price

Model fit Statistics					
SARIMA(4,1,4)$(1,0,1)_{12}$	**R^2**	**RMSE**	**MAE**	**MAPE**	**Runs test**
	0.94	493.31	277.72	4.35	p=0.14

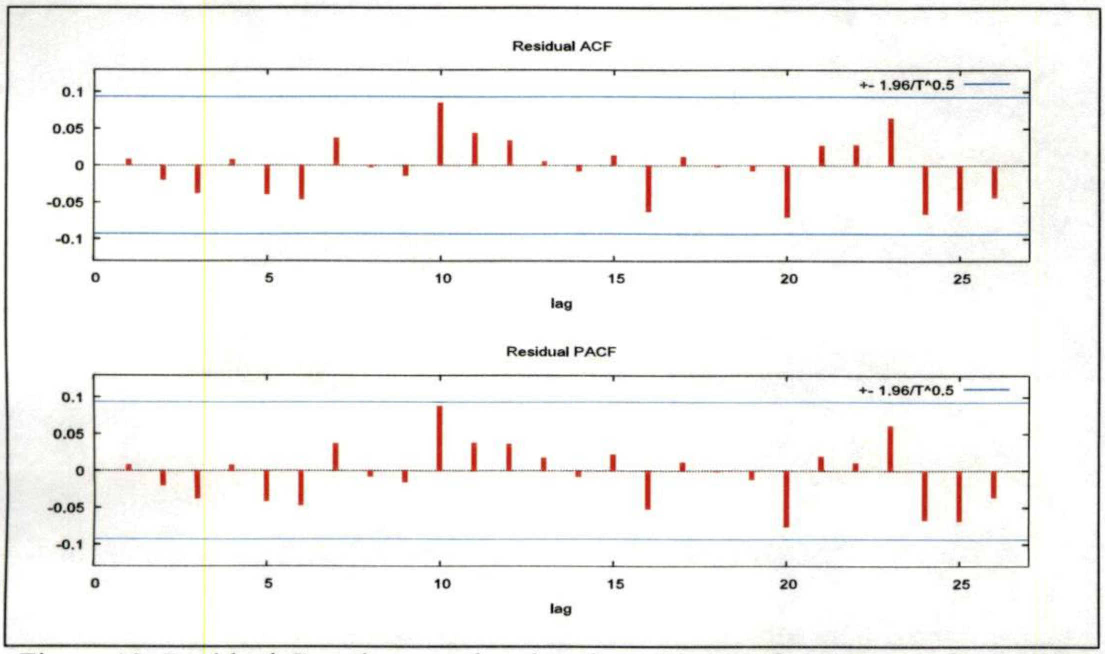

Figure 19: Residual Correlogram showing the evidence of stationarity for SARIMA (4,1,4) $(1,0,1)_{12}$ model

This model explains 94 per cent of the variation in the domestic NR price data. Residual ACF and PACF plots are presented in Figure 19. From the graph, it is clear that majority of the spikes in ACF and PACF plots were within the critical values. This proves additionally, the adequacy of ARIMA (4,1,4) $(1,0,1)_{12}$ model for domestic NR prices.

4.5.3.3. Validation checking for domestic NR prices using SARIMA (4,1,4) $(1,0,1)_{12}$ model

The validation period for SARIMA (4,1,4) $(1,0,1)_{12}$ was taken as six months. The forecasts were generated for the validation period and all the observations were found to be within the confidence limits as shown in Table 4.32 and given in the Figure 20. The predicted values approximated very much by the actual values. By this, it could be proved that the model ARIMA (4,1,4) $(1,0,1)_{12}$ assumed was realistic.

Table 4.32 Validation for domestic NR price SARIMA (4,1,4) $(1,0,1)_{12}$ model

Year & month	Actual values	Predicted value	Difference	Std.Error	Confidence limit
2016:07	12745	11968.53	776.47	469.60	11048.14-12888.92
2016:08	13744	12133.10	1610.90	760.40	10642.74-13623.46
2016:09	13470	12204.42	1265.58	981.56	10280.59-14128.25
2016:10	12058	12325.45	-267.45	1199.63	9974.22-14676.68
2016:11	12510	12315.62	194.38	1390.82	9589.66-15041.58
2016:12	13098	12298.40	799.60	1529.31	9301-15295.8

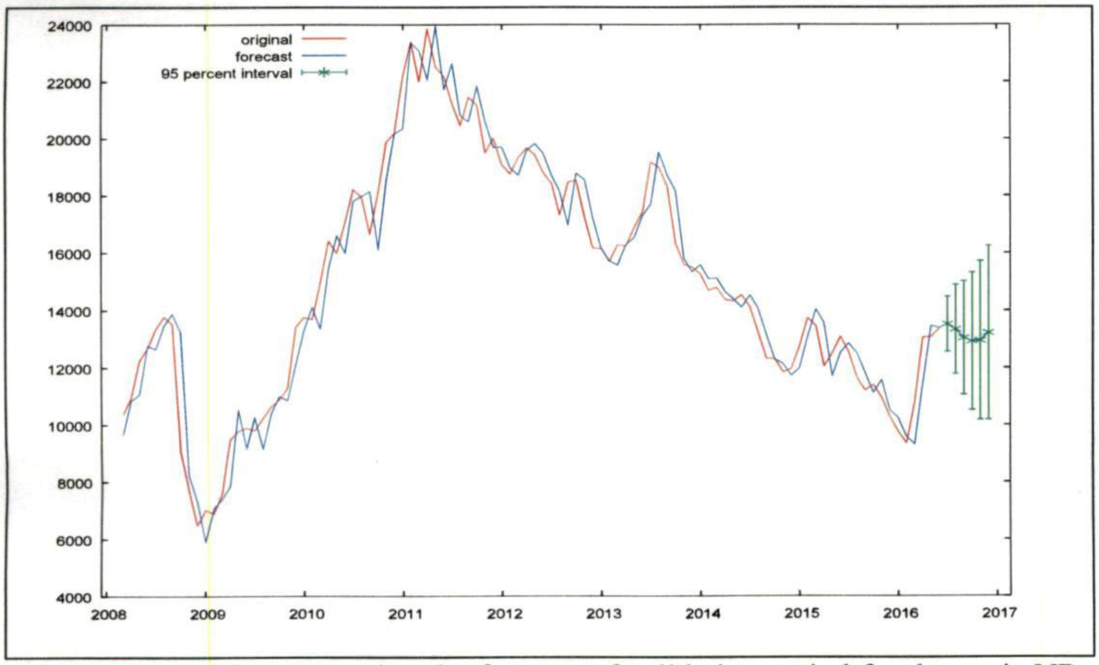

Figure 20: Graph representing the forecast of validation period for domestic NR price using SARIMA (4,1,4) $(1,0,1)_{12}$ model

4.5.3.4. Forecasting of domestic NR prices using SARIMA (4,1,4) $(1,0,1)_{12}$ model.

As the forecast was good for the validation period, the prediction was taken for six months and the predicted values are given in Table 4.32 and Figure 21.

Table 4.33 Forecast values for domestic NR price using SARIMA (4,1,4) $(1,0,1)_{12}$ model

Year and	Predicted	Std. Error	Confidence limit
2017:01	13911.87	493.30	12945.01-14878.73
2017:02	14235.39	804.38	12658.88-15811.9
2017:03	14378.31	1027.58	12364.27-16392.34
2017:04	14263.57	1247.30	11818.91-16708.24
2017:05	13914.17	1440.87	11090.18-16738.15
2017:06	13773.72	1577.88	10681.21-16866.22

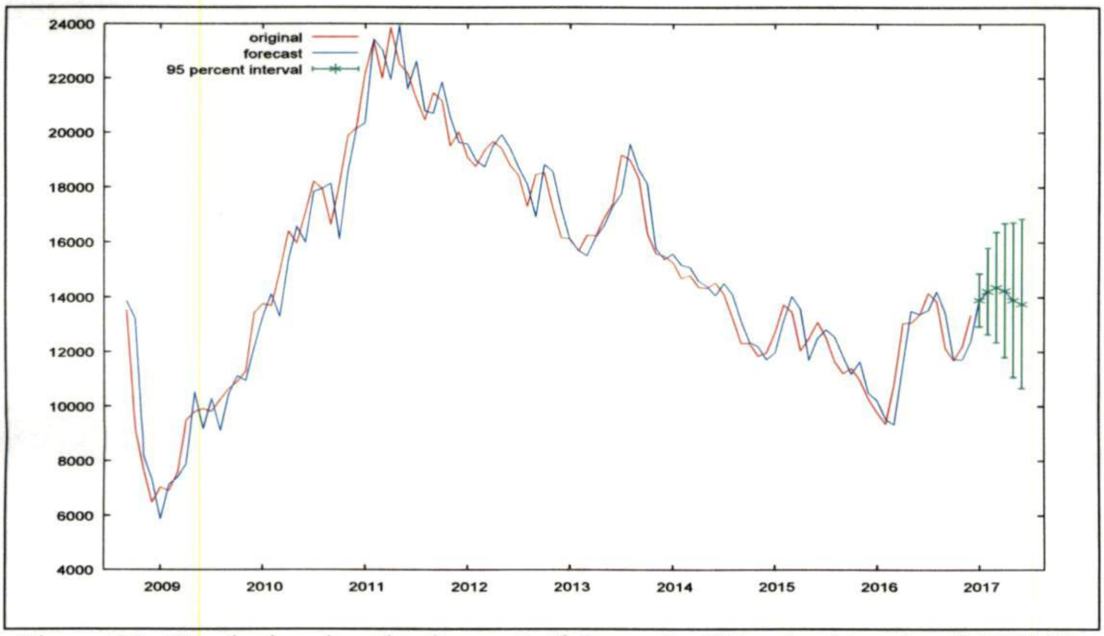

Figure 21: Graph showing the forecast of domestic NR price by using SARIMA (4,1,4) $(1,0,1)_{12}$ model

A similar result was obtained for monthly average prices of Arabica and Robusta coffee (Yashavanth, 2010). He found SARIMA (0,1,1) $(1,1,1)_{12}$ and SARIMA (4,1,1,) $(4,1,1)_{12}$ respectively for Arabica and Robusta coffee, with low AIC and BIC. He çoncluded that the prices were related to their past values, as there was presence of non-seasonal and seasonal MA terms which were significant.

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Summary

5. SUMMARY

The study entitled "Time series analysis and forecasting of the prices of Indian Natural Rubber" is primarily intended to forecast the prices of Indian Natural Rubber (NR). For forecasting the prices, firstly, domestic rubber price was decomposed into time series components. Evaluation of growth, instability and relationship between the domestic and international prices in the pre-WTO, post-WTO and overall periods were carried out in this study.

The decomposition of domestic rubber prices into time series components was carried out under the assumption of additivity. The price data was decomposed into trend, seasonal and cyclic components. The trend values proved that there was quadratic trend over the years. By trend values, it was concluded that from the year 1995, there was a great variation in domestic price. The estimated seasonality indices revealed that the highest price was in June and lowest price in December. The cyclical components showed three cycles over the period of time under investigation i.e., from the year 1980-1992, 1992-2002 and 2002-2016.

For evaluation of growth and instability of NR prices, volatility and instability analysis were carried out for pre-WTO, post-WTO and overall periods for prices rupees as well as US dollars. Two types of volatility i.e., intra-annual volatility (within the year dispersion) and inter annual volatility (between year dispersion) were calculated. When the prices were considered in rupees, intra-annual volatility ranged from 0.17 to 1.26, 0.16 to 1.27 and 0.13 to 1.77 for domestic prices, international prices and crude oil prices respectively. In terms of US dollars, intra-annual volatility ranged from 0.17 to 1.35, 0.12 to 1.29 and 0.13 to 1.76 for domestic NR prices, international NR prices and crude oil prices respectively. Among the three periods, post-WTO period showed high intra-annual volatility for domestic and international NR prices while for crude oil prices, it was high in pre-WTO period. For prices of rupees, inter-annual volatility ranged from $\Delta 0$ - 0.30, $\Delta 0$ - 0.35and $\Delta 0$ - 0.37 for domestic NR prices, international NR prices and crude oil prices respectively. When the prices were considered in US dollars, inter-annual volatility ranged for domestic NR prices, international NR prices and crude oil prices from 0.0004 to 0.360, 0.0008 to 0.41 and $\Delta 0$ to 0.41 respectively. Among three periods, post-WTO period showed higher inter-annual volatility for domestic and international NR prices whereas for crude oil prices was high in pre-WTO periods. GARCH (1,1) model gave an additional evidence for persistence of volatility in NR prices. It proved that the volatility persisted in the overall period for prices in both rupees and US dollars for domestic NR price and for international NR price; Volatility was very high for prices in terms of rupees and it even persisted when prices were considered in terms of dollars. Instability analysis showed that the price instability in post-WTO period was almost double than that of pre-WTO period and it tripled in the overall period for all prices.

The relationships between domestic and international prices were analyzed through cointergration analysis and Vector Error Correction Model (VECM). The direction of relation was drawn by causality test. Co-integration and causality tests proved that there was at least unidirectional relationship among the variables. VECM analysis proved that there was long run relationship between domestic NR price, international NR price and crude oil price. It revealed that, a speed rate of adjustment 14.3 per cent was required for domestic rubber to correct its previous period.

There were many factors affecting the prices of Indian NR like synthetic rubber (SR) production, SR consumption, crude oil prices, international rubber prices, international demand and supply, international transactions, exchange rates, natural factors and development of automobile industries. The major factors influencing the prices of domestic NR in the pre-WTO and post-WTO periods were found using stepwise regression analysis. Separate factors were sorted out affecting in pre-WTO and post-WTO using step wise regression analysis. The analysis revealed that NR price in pre-WTO was affected by international NR prices and in post-WTO by international NR prices and SR consumption.

Domestic NR prices were forecasted with three different methods like stepwise regression, ARIMA and SARIMA. In stepwise regression method, annual domestic NR price could be predicted only when annual international NR price and annual import values are available. For ARIMA modelling, different models were tried and among them, ARIMA (4,1,4) was found best which was proved by diagnostic checking like AIC and BIC criteria. Model fit statistics like RMSE, MAE, MAPE were carried out for the selected model. The validation period was taken for six months i.e., from July 2016 to December 2016 and so forecasted for another six months i.e., January 2017 to June 2017. And for SARIMA modelling, SARIMA (4,1,4) $(1,0,1)_{12}$ was found best among different models tried. The model was selected by diagnostic checking like AIC and BIC criteria and model fit statistic like RMSE, MAPE and MAE were calculated to prove the model was the best. Validation period was taken for six months i.e., from July 2016 to December 2016 and forecasted for another six months i.e., January 2017 to June 2017.

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Appendices

Appendix I: Trends values for domestic NR prices from year 1980-2016

Year	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec
1980	0.0	0.0	0.0	0.0	0.0	0.0	1168.6	1197.4	1226.7	1259.2	1295.6	1332.5
1981	1357.5	1371.4	1382.1	1389.7	1400.8	1415.5	1428.6	1441.3	1454.2	1464.8	1471.5	1475.3
1982	1485.1	1498.8	1506.6	1502.6	1492.8	1481.1	1465.9	1454.2	1445.0	1441.4	1453.7	1476.3
1983	1496.3	1515.3	1540.7	1573.3	1608.9	1649.4	1690.2	1719.4	1740.9	1754.8	1752.5	1743.9
1984	1743.5	1744.3	1735.8	1725.5	1714.6	1698.0	1681.4	1668.1	1658.6	1651.1	1649.4	1649.8
1985	1644.5	1639.3	1643.3	1656.2	1673.0	1688.0	1700.6	1713.5	1725.7	1737.3	1742.9	1741.5
1986	1736.5	1729.5	1718.5	1702.8	1686.9	1674.4	1665.5	1660.7	1660.0	1663.6	1671.5	1682.0
1987	1695.8	1709.2	1720.6	1733.7	1747.2	1759.7	1772.2	1783.0	1788.9	1788.3	1783.0	1778.6
1988	1775.8	1777.8	1787.4	1800.0	1808.2	1810.7	1809.9	1809.0	1812.2	1818.9	1833.1	1864.0
1989	1914.3	1969.5	2001.1	2007.1	2013.0	2029.3	2056.7	2088.1	2116.7	2145.7	2170.8	2186.2
1990	2180.7	2149.9	2132.2	2139.7	2146.8	2147.7	2141.8	2135.3	2131.1	2124.4	2114.0	2095.5
1991	2078.4	2084.3	2098.0	2104.7	2113.9	2123.7	2129.1	2129.1	2134.4	2159.3	2195.4	2231.3
1992	2266.6	2294.4	2318.8	2349.8	2382.8	2416.8	2455.9	2503.9	2541.9	2547.5	2536.6	2524.6
1993	2510.3	2496.9	2486.4	2472.6	2458.0	2444.6	2426.5	2405.4	2399.9	2419.6	2455.0	2505.9
1994	2595.1	2713.0	2833.8	2972.8	3123.1	3284.4	3483.8	3716.5	3959.7	4200.3	4416.3	4577.5
1995	4652.3	4666.5	4686.9	4725.6	4801.3	4894.5	4945.5	4957.7	4936.9	4876.2	4819.5	4808.1
1996	4829.0	4860.2	4877.7	4855.5	4787.5	4695.9	4602.7	4505.3	4417.5	4350.0	4274.8	4188.7
1997	4094.1	3992.8	3889.3	3786.8	3679.7	3548.0	3398.9	3268.0	3154.0	3049.8	2973.1	2899.8
1998	2844.6	2810.3	2778.0	2763.6	2760.6	2766.7	2792.5	2802.0	2781.3	2746.6	2696.9	2653.5
1999	2613.2	2573.2	2543.8	2518.2	2511.0	2519.8	2517.5	2529.2	2564.9	2609.4	2661.3	2706.7

2000	2746.4	2794.7	2842.3	2872.5	2877.5	2876.4	2887.9	2878.0	2846.3	2815.8	2789.9	2774.3
2001	2766.3	2749.6	2722.5	2692.5	2661.8	2623.6	2593.1	2595.8	2632.6	2693.1	2763.4	2850.8
2002	2950.3	3046.2	3145.0	3245.2	3342.0	3467.9	3615.0	3746.6	3863.5	3989.0	4111.8	4199.8
2003	4261.1	4327.1	4412.3	4519.5	4651.0	4767.2	4849.4	4918.6	4996.0	5069.1	5140.3	5245.3
2004	5396.1	5520.5	5570.3	5588.4	5587.7	5576.6	5577.9	5582.7	5575.9	5573.5	5591.0	5598.8
2005	5591.8	5613.3	5670.9	5760.4	5870.3	5997.7	6153.8	6359.8	6589.8	6815.4	7083.0	7422.4
2006	7746.5	8011.3	8229.4	8408.1	8568.4	8711.0	8881.3	9050.8	9163.3	9218.8	9185.0	9028.5
2007	8842.0	8745.4	8755.7	8814.1	8899.9	8981.1	8994.5	8979.8	9030.9	9167.7	9398.9	9739.6
2008	10156.8	10591.7	10996.7	11177.1	11082.4	10888.5	10674.	10458.8	10227.	10050.	9887.0	9668.7
2009	9405.5	9111.7	8844.3	8800.1	9027.0	9467.1	10037.	10601.0	11191.	11786.	12332.	12889.
2010	13538.0	14208.8	14779.4	15329.8	15987.6	16626.4	17257	18011.2	18709	19313	19896	20381
2011	20720.0	20950.7	21255.8	21584.5	21696.9	21674.8	21540	21219.5	20915	20630	20327	20057
2012	19799.5	19551.0	19295.1	19060.0	18855.4	18600.3	18316	18065.2	17809	17538	17288	17124
2013	17097.8	17199.1	17262.8	17164.6	17004.3	16908.1	16844	16766.5	16663	16525	16341	16116
2014	15785.3	15335.1	14846.4	14430.2	14107.4	13804.9	13553	13408.1	13312	13160	12987	12850
2015	12724.7	12592.9	12480.6	12396.1	12320.3	12211.6	12017	11710.7	11417	11348	11413	11448
2016	11528.6	11688.0	11817.5	11867.8	11932.0	12113.3	0.0	0.0	0.0	0.0	0.0	0.0

TIME SERIES ANALYSIS AND FORECASTING OF THE PRICES OF INDIAN NATURAL RUBBER

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ABSTRACT OF THE THESIS

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Abstract

The study entitled "Time series analysis and forecasting of the prices of Indian Natural Rubber" is primarily intended to forecast the prices for Indian Natural Rubber (NR). For forecasting the prices, firstly, domestic NR price was decomposed it into time series components. Evaluation of growth, instability and relationship between the domestic and international prices in the pre WTO and post WTO periods were carried out in this study.

For decomposition of domestic NR prices into time series components, additive decomposition was tried. The data were decomposed into trend, seasonal and cyclic components. The trend values proved that there was quadratic trend over the years. Seasonality indices revealed that the highest price was in June and lowest price in December. Cyclic components showed three cycles over a period of time under investigation.

For evaluation of growth and instability, volatility and instability analyses were carried out for pre-WTO, post-WTO and overall periods in terms of rupees as well as dollars. Two types of volatility i.e., intra-annual volatility (within year dispersion) and inter annual volatility (between year dispersion) were calculated. Intra-annual and inter annual volatility were higher in post-WTO for international and domestic NR price series and the crude oil price showed higher volatility in pre-WTO period in terms of rupees as also in dollars. GARCH (1,1) model gave an additional evidence for persistence of volatility. It proved that the volatility persisted in the overall period in terms of rupees and dollars for domestic and international NR price. Instability analysis showed that the price instability in post-WTO period was almost double than that of pre-WTO period and it tripled in the overall period in terms of rupees. In terms of dollars, the instability in post-WTO and overall period was almost triple than pre-WTO period for domestic and international NR prices and crude oil prices showed almost double instability than pre-WTO period.

The relationship between domestic and international NR prices were analysed through cointergration analysis and Vector error correction model (VECM). The direction of relation was drawn by Granger Causality test. Cointegration and Granger Causality test proved that there was at least unidirectional relationship among the variables. VECM analysis proved that there was long run relationship between domestic NR price, international NR price and crude oil price. It revealed that, a speed rate of adjustment 14.3 per cent was required for domestic NR price series to correct its previous period.

There were many general factors affecting the prices of domestic NR like synthetic rubber production, crude oil prices, international rubber demand and supply, international transactions, exchange rates, natural factors and development of automobile industries. Stepwise regression analysis was used to sort out the factors affected in pre-WTO and post-WTO periods. In pre-WTO, domestic NR price was affected by international NR prices and in post-WTO by international NR prices and SR consumption.

Domestic NR prices were forecasted with three different models like Stepwise regression method, ARIMA and SARIMA models. Stepwise regression method could be predicted when the variables like international NR prices and import value of NR were available. Among ARIMA and SARIMA models, ARIMA (4,1,4) and (4,1,4) $(1,0,1)_{12}$ was found to be best judged as per different statistical criteria for assessing the model fit and model adequacy.