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DYNAMICS OF INDIA'S TEA PRODUCTION: AN ECONOMETRIC ANALYSIS

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Abstract- Aggregate annual production of made tea in India is empirically analyzed in this study using time series analysis techniques. Important factors affecting tea production are identified and modeled using Vector Autoregressive (VAR) model taking two variables at a time of which one is production, the variable of interest.

Index Terms- Production, Prices, VAR, Cointegration, Integration, Transmission, Intervention

I. Introduction

World tea production reached 4527 million Kilograms in 2012 and China that holds the largest market share dominates the market. India was the market leader at the international level with regard to production and consumption of tea till 2005. At present, India is the second largest producer of tea in the world and produces around 1112 million kilograms of tea accounting for 24.56% of tea produced worldwide. The tea industry accounts for the employment of more than 2 million people in India. It occupies an important role in the Indian economy not only due to its capacity to earn foreign exchange, but also because it impacts the livelihoods of scores of people employed directly and indirectly by the industry.

Since 1990s, the Indian tea industry has been experiencing a decline in prices in the auction market due to falling demand which has been primarily attributed to poor quality. Although the annual production has been increasing, the productivity and yield have not shown any improvement. The problem has been further worsened by a poor export performance which has been attributed to high production costs, poor quality and increasing global competition from emergence of new growers like Vietnam, Indonesia and Kenya. All this have led to the revenue from the tea industry falling by leaps and bounds. The other issue that has been plaguing the Indian tea industry is the existence of high percentage of ageing tea bushes. The economic age of tea bushes that is required for good yield of crops is 5 to 40 years. A continuous stand of tea plants for more than 50 years exhausts the soil of its mineral supply, thereby reducing plant growth and hence profitable yields.

Owing to the above mentioned factors and the nuances involved in the tea manufacture, it is a unanimously accepted view of agricultural economists that tea warrants extensive research. Studies that enhance the clarity on different factors affecting tea production are extremely desirable considering the problems tea industry has faced over the years.

II. FEATURES OF THE INDIAN TEA INDUSTRY

The birth of Indian tea industry was marked by the discovery of indigenous teas plant in Assam in 1823 by Robert Bush. This received momentum when the East India Company in 1833 lost the tea trading monopoly in China. In 1835, a scientific deputation was sent to Assam to report on prospects of the tea industry and the team saw tea plants in many parts in the hills between Assam and Burma. In 1836, C.A. Bruce was made the Superintendent of Tea Forests. Among others, he formed the Bengal Tea Company at Calcutta with the objective of purchasing the produce from the East India Company's tea plantations in India. A similar Company was also established in the same year in London with the same objectives. In 1839 the first consignment of tea from India (eight chests) was shipped to London and it was auctioned at a price ranging from six to thirty four shillings per pound. In 1840, two thirds of experimental teas were handed over to new company. In 1852, the first tea company in India paid its final dividends. The second limited company in 1859 was formed in Assam called Jorhat Company. During 1862-67, tea cultivation started in Chittagong and Chotta Nagpur. Ultimately tea cultivation was commissioned in many districts in India wherever there was some hope of a success. Within a few months, India along with Sri Lanka dominated the world tea trade/market.

The essential features of the tea industry include (i) Farming and Manufacturing, (ii) Geographical Locations, (iii) Marketing,(iv) Exports, (v) Internal Consumption, (vi) Import, (vii) Labour.

III. OBJECTIVES OF THE STUDY

The study intends to analyze two important aspects of tea industry namely production and price. The broad objectives of the study include:

- Identifying factors affecting tea production in India
- Modeling of Annual tea production with the identified factors

IV. LITERATURE REVIEW

There are a number of studies on modeling of tea production in Pakistan and other parts of Southeast Asia most of which consider climate related factors predominantly while some have even considered soil related factors for modeling. Chatterjee (2005) conducted a study on the domestic production, domestic consumption and exports of Indian tea and examined their inter linkages. The study examines possible reasons for stagnating export volumes of Indian tea industry by analyzing the inter linkages between production, consumption and exports of tea and also developing export function. The production function takes only the acreage and price as important variables in the model. The three models developed for supply, demand and export are analyzed together using the SUR (Seemingly Unrelated Regression) technique and the correlation between the disturbances of the three equations are estimated using generalized least squares method. The results of the study indicate that India did not experience a fall in tea exports in the USSR period due to favorable terms of trade with the USSR, while in the post USSR period, competition increased and hence Indian tea exports declined. It also highlights that tea in India is a necessity good as income elasticity is low.

Thomas & Ahmad (1970) conducted a study on the factors affecting tea production in Pakistan. The total domestic absorption of tea in Pakistan is regressed with time as the independent variable and it has been found that there is a steady increase in absorption at the expense of declining exports. Acreage has been on the rise but tea production does not show an increasing trend. The short run fluctuations in tea production has been analyzed taking into account factors like rainfall, temperature, Lang's factor (rainfall/temperature) and number of rainy days in a year. The results indicate that the quantity of rainfall is not closely related to production. On the other hand, rainfall has significant correlation with production in the not-so-cool months. The Lang's factor is found to be conceptually weak and the number of rainy days is found to have significant correlation with tea production both on a month-to-month and annual basis.

Gupta & Dey (2010) conducted a study on the development of productivity measurement model for tea industry. This study has made an attempt to address the issue of declining production and unsatisfactory productivity performance of the Indian tea industry. It proposes a relatively simple productivity measurement model suited to tea industry. Productivity accounting model is used and suitably given the form so as to fit to a tea industry. The performance of the model is assessed by applying it to tea industry in Assam and it has been found that the model is comprehensive and satisfies all the six criteria of measurement theory such as validity, comparability, completeness, timelines, inclusiveness and cost-effectiveness. The model also identifies areas of poor resource (labour, material and energy) utilization responsible for total productivity decline in the tea industry.

Baten, Kamil & Haque (2009) conducted a study on modeling technical inefficiencies effects in a stochastic production function for panel data. The inefficiency effects are assumed to be independently distributed as truncations of normal distributions with constant variances but with means which are linear functions of observable variables. Panel data is used in this study to estimate the production frontier and the technical inefficiency effects of tea production using a Stochastic Frontier Analysis (SFA) methodology. The study observes that Stochastic Frontier Translog Production Function is more preferable compared to Stochastic Frontier Cobb-Douglas Production Function. The findings suggest that 49% technical inefficiency exists in tea yield. The null hypotheses, that inefficiency effects are not stochastic or do not depend on the labor-specific variables and time of observations, is rejected for these data. This study also reveals that there is a negative relationship between size and yield.

Krishnadas (2010) conducted a study on production and export performance of major Indian spices. The objectives of the study are to analyze the growth in area, productivity and production of major spices in India, to analyze the instability in production of major Indian spices, to examine the growth in exports and direction of trade of major spices from India and to examine the factors influencing changes in production and export of major spices. The following analytical techniques are employed viz. Compound growth rate analysis for computing the growth rate on area, production, yield and exports; Instability analysis to compute the extent of variability in area, production, productivity and export of major spices using coefficient of variation; Markov chain analysis to analyze the trade directions of Indian spice exports and Multiple Linear Regression to identify the factors influencing the production of major spices.

Akhlas, Ahmad, Siyar & Khanum (2003) conducted a study on qualitative assessment of fresh tea produced in Pakistan growing under different agro ecological conditions and fertilizer treatments. The objective is to evaluate the effect of plucking season, altitude and agronomic practices upon quality of tea using trials initiated in 1998 at Shinkiari (1000 m) and Battal (1500 m) on mature tea bushes. Analysis of variance technique is used which shows that increasing nitrogen treatments and different seasons have a significant influence on Epigallocatechin (EGC), Epicatechin (EPC) and Caffeine level of tea leaves at both localities. The results show that tea produced in Pakistan contains constituents in premium concentration highly desirable for Black tea processing.

Dutta (2011) conducted a study on impact of age and management factors on tea yield and modeling the influence of leaf area index on yield variations. The study attempts to analyze the effects of age, pruning and fertilizer application on tea yield and to derive a relation between yield and tea leaf area index (LAI). The study is motivated by the fact that tea yield has stagnated in Northeast India. For the purpose at hand, statistical analysis is applied to the data set collected at the section level of a tea estate from 1999-2007. Tea yield has been found to be correlated with age, NPK applications, pruning and also leaf area index. Age shows a significant negative effect. Clear negative effects of N applications could be observed. A significant positive effect of pruning could also be observed. Stepwise regression confirms that LAI could play an important role in predicting tea yield.

Hicks (2009) conducted a study on the current status and future development of global tea production and tea products to identify the critical challenges faced by the tea industry globally. It examines the current situation and medium term prospects for production, consumption and trade of tea and its impact on the world tea market. The following factors are taken to be affecting global tea production: weather conditions, planted areas, population, age of tea bushes, labor, capital, price of inputs and yield risk. The factors taken to be affecting global consumption are income of the country, quality of the products and substitutes and complements available, etc.

From the review of this exhaustive literature on tea production, it can be seen that although tea production has been dealt with by many researchers, there seems to be dearth of research work related to this in India. Considering the importance of tea industry in India, in terms of income, foreign exchange earnings and being a significant employment provider, it seems essential to identify factors that significantly impact tea production and model them with the objective of providing good forecast.

V. LITERATURE REVIEW

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VI. DATA AND METHODOLOGY

Yearly data for the period (1991-2011) was used for production and other factors that were identified from literature and assumed to be affecting it. In some cases, for the purpose of getting a stable model, the data has been subjected to log transformation which has been explained in the next section on results and analysis. The factors that were assumed to be apriori affecting production are Area under cultivation of Tea, Domestic Consumption, Price, Rainfall, Temperature, Age of Tea Bushes, Labour, Area under plucking, GDP at Market prices, Revenue through Cess and Number of Suppliers.
The methods used in time series analysis for modeling production and other variables are ARIMA (Auto Regressive Integrated Moving Average) model for the univariate case and VAR (Vector Auto Regressive) model for the multivariate case. A complete description of these methods is beyond the scope of this chapter but concise descriptions of facts pertaining to the model that have direct connotation to our modeling work are presented here.

A VAR model describes the evolution of a set of k variables (called *endogenous variables*) over the same sample period (t = 1... T) as a linear function of only their past values. The variables are collected in a $k \times 1$ vector y_t, which has as the i^{th} element, $y_{i,t}$, the time t observation of the i^{th} variable. For example, if the i^{th} variable is GDP, then $y_{i,t}$ is the value of GDP at time t.

A *p-th order VAR*, denoted **VAR (*p*)**, is

$$y_t = c + A_1 y_{t-1} + A_2 y_{t-2} + \cdots + A_p y_{t-p} + e_t,$$

Where the l-periods back observation y_{t-1} is called the l-th ***lag*** of y, c is a $k \times 1$ vector of constants (intercepts), A_i is a time-invariant $k \times k$ matrix and e_t is a $k \times 1$ vector of error terms satisfying

1. $\mathrm{E}(e_t) = 0$ — every error term has mean zero;

2. $\mathrm{E}(e_t e_t') = \Omega$ — the contemporaneous covariance matrix of error terms is Ω (a $k \times k$ positive-semi definite matrix);
3. $\mathrm{E}(e_t e_{t-k}') = 0$ For any non-zero k — there is no correlation across time; in particular, no serial correlation in individual error terms.

The order of VAR model is identified based on various criteria such as AIC, SC, HQ and FPE. Finally after the model has been estimated, it is used for understanding the dynamics of other variables on the variable of interest by looking at the coefficients and also based on causality studies. Also the estimated model will be used for forecasting future values of all the variables. A 'Structural VAR' is a depiction of the underlying "structural", economic relationships between the variables under consideration. Two features of the structural form that make it the preferred candidate to represent the underlying relations include residuals being uncorrelated and presence of contemporaneous impact between variables.

A. *Univariate Modeling*

First the univariate case is taken and modeling is done to study the dynamics of annual production of made tea in India. This throws light on the presence or absence of trends, seasonality, cyclicity and irregular components if any in the series. The importance of univariate modeling cannot be underpinned as it helps in understanding if the series is stationary or differencing is required and if the production is expected to show an increasing or decreasing trend in future. Then in the subsequent stages of analysis, when other variables are considered for modeling, it will clearly highlight the impact that these variables have on the production of made tea.
The variable under consideration for modeling is the production of made tea in India (in Kg) which is the sum of the quantities of CTC, Orthodox, Darjeeling and Green teas produced in India. The unit of the variable is Million Kgs and the period for which data are used is from 1991 to 2011.
The time series plot of production is first analyzed to see if there are any discontinuities or outliers in the data for the period under consideration and to account for the same if any.

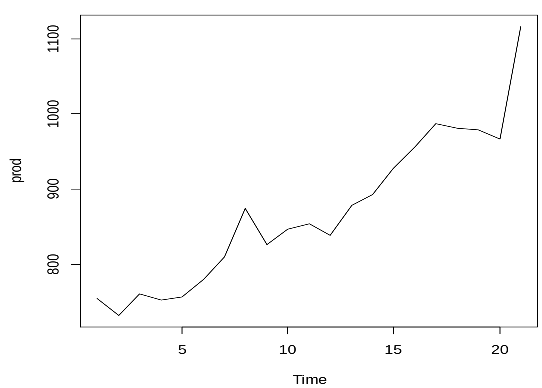

Figure 2.1: Time Series Plot of Production

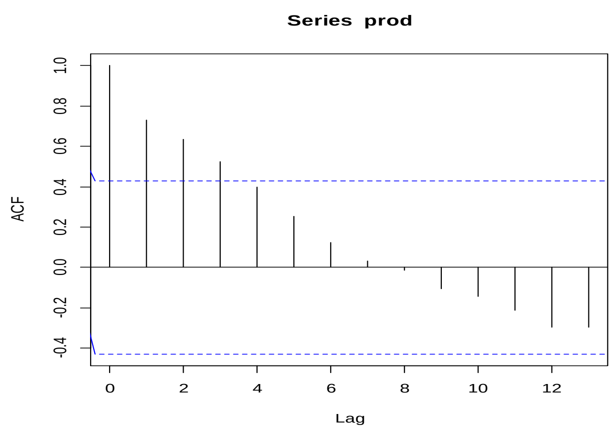

Figure 2.2: ACF of production

From the plot in figure 2.1 we infer that the production of made tea seems to have an increasing trend on the whole with some sharp peaks in the years 1998 and mid 1999. It was in the year 1999, that the Indian tea industry suffered a serious crisis triggered by a big fall in the auction prices and export prices and eventually led to a lot of tea estates closing down. This can be naively related to the upsurge in the production that we see from the plot. The increase in production was not balanced by an increase in domestic consumption of tea in India. The export performance was also not attractive owing to increased competition from the new players in the international market and deteriorating quality of Indian made tea. These factors would have led to a decline in prices and eventually led to crisis.
As far as the modeling is concerned, there seems to be an increasing trend and hence it can be naively concluded that differencing may be required which is again confirmed from the ACF (Auto Covariance Function) plot shown in figure 2.2 that shows a slow decline in ACF. But owing to less number of data points, one cannot go by ACF plot. Hence unit root tests are carried out to confirm this. ADF and PP tests had p values of 0.4349 and 0.05178 for the raw series which are high (if we want 95% significance) and hence this confirms the presence of unit roots in the lag polynomial and need for differencing. Then the same tests were performed for the differenced series. PP test had p value of less than 0.01 thereby confirming that once differencing may be sufficient.
Now, the time series plot, ACF and PACF of the differenced series as shown in figures 2.3, 2.4 and 2.5 are analyzed to see if more differencing is required. The time series plot of the differenced series in figure 2.3 shows that some volatility is present in the data which might be because of the presence of limited number of data points. The ACF and PACF plots in figures 2.4 and 2.5 also seem to be fine with all the values at different lags within the confidence boundaries (dotted lines).

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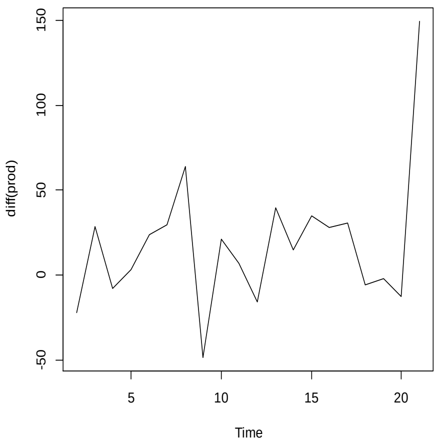

Figure 2.3: Plot of differenced

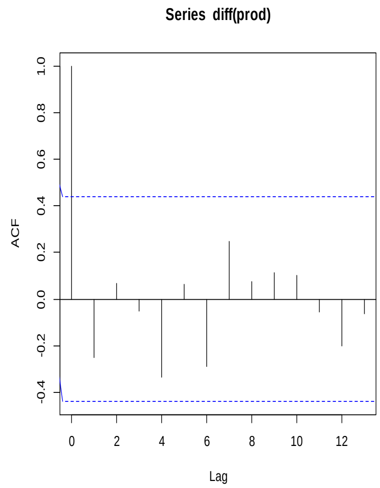

Figure 2.4: ACF of differenced Production series

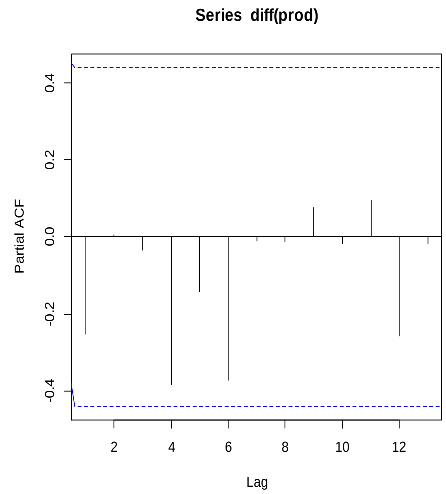

Figure 2.5: PACF of differenced Production series
Production series

Now the emphasis is on building a suitable model for production keeping in mind that a first order differencing is required. AIC (Akaike Information Criterion) is the tool that is used to select the model with proper order. The model with least AIC is the one that is preferred. The final selected model is as follows:
ARIMA (0, 1, 0) model is selected and the equation is as follows:
$DX_t = \varepsilon_t$, where $DX_t = X_t - X_{t-1}$
AIC of the model is 209.331 and that happens to be the least of all other models tried.
Once modeling is done, it is customary to check if the residuals are white noise failing which modeling will still remain incomplete. The differenced series plot in figure 2.3 looks stationary. Also as pointed out before, ACF and PACF plots also look alright. Box-Pierce, Ljung Box and Kolmogorov Smirnov tests are carried out to check if the residuals of the model are white noise. The p values of the three tests are 0.9948, 0.9788 and 0.8059 respectively which are high thereby implying that the residuals are indeed white noise.
The next and most important task is prediction of future values of production. But the model is a simple random walk and hence the best estimate of production in 2012 is the value in 2011 itself.
With the univariate case in the backdrop, more variables are considered to study their impact on the production of made tea.

B. Bivariate Modeling

Variables considered for Modeling Production: Area under cultivation of Tea, Domestic Consumption, Price, Rainfall, Temperature, Age of Tea Bushes, Labour, Area under plucking, GDP at Market prices, Revenue through Cess, Number of Suppliers and Bearing area, Domestic Average Coffee Price and Relative auction price of tea.
All variables are integrated of different order and hence VAR is used for modeling as opposed to Cointegration.
In this study, since yearly data from 1991 to 2011 is used for modeling, all variables that were assumed to be affecting production could not be taken in a single run (owing to less number of data points) and hence Structural VAR with production (variable of interest) as the second variable is carried out and the results of models with production on the left hand side and other variables on the right hand side are shown and delineated.

C. Production and Consumption

Production denotes the supply and Consumption, the demand in the context of made tea. The objective is to model both the variables and see if there is any impact of consumption on production. In general from theory of economics, it is known that there is an inverse relationship between price and demand and direct relationship between price and supply. Also if the demand is high, producers will produce more as gains are high. But there is a complexity involved in interpreting the relationship as the methodology that is going to be adopted here is VAR (Vector Auto Regressive) modeling. In this method, there could be as many lags as the order of the model and consumption could affect production differently in different lags. Hence the complexity involved actually lies in interpreting how consumption affects production at different lags. The results of the modeling are as follows:
Period of Study: 1991-2011
The variables are Log transformed to make the VAR model stable.
First the raw time series plots of production and consumption are analyzed to see if there are any discontinuities and outliers in the data. The production and consumption plots are shown in figures 2.1 and 2.5 respectively.

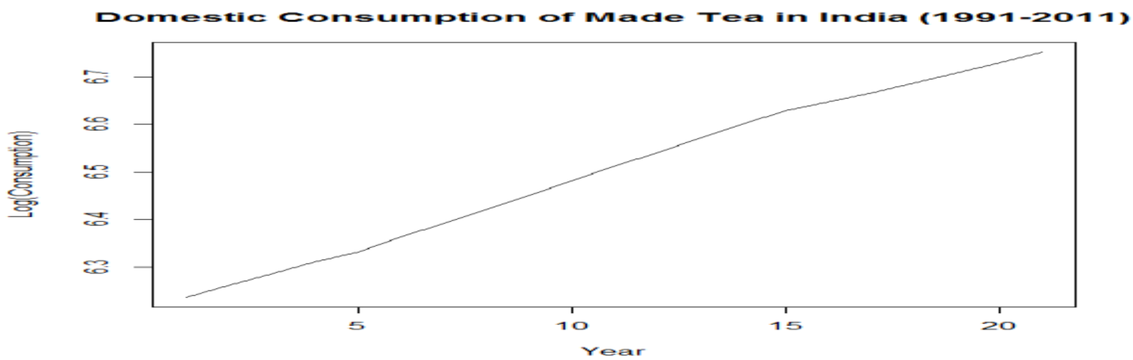

Figure 2.6: Time series plot of Consumption

From the plot, it can be inferred that both production and consumption show an increasing trend and that consumption has much lesser volatility or deviations. The optimal order of the model is found to be one based on AIC, HQ, SBC and FPE. The final model with only significant terms is shown below:

$Prod_t = 0.6129*Cons_{t-1} + 2.7840 + \varepsilon_t$
(0.0358) (0.2325)

From the first order model, the following can be inferred:

When the consumption at time (t-1) increases by one unit, production at time (t) will increase by 0.6129 units. There seems to be a direct relationship between production and consumption with the rate of increase or decrease in production lesser than that in consumption. The fact that there is a direct relationship between production and consumption is understandable as producers will produce more when they see an increase in demand. But unlike other commodities, tea production cannot be increased without planting more tea crops or in other words, increasing the area under cultivation of tea. Moreover, it will take 5 years for the tea crops to mature after which tea crops can be used for production of made tea. But the model says that when consumption at time (t-1) increases, production at time (t) will increase. This is because many tea companies don't operate at the maximum capacity and many factories buy only tea leaves from tea growers to the extent of what is required. Hence it's always possible to increase production up to a certain level when an increase in demand is seen. But the issue here is as pointed out earlier, the rate of increase or decrease in production is lesser than that in consumption.

Now the model is plotted to see how well it matches the actual data.

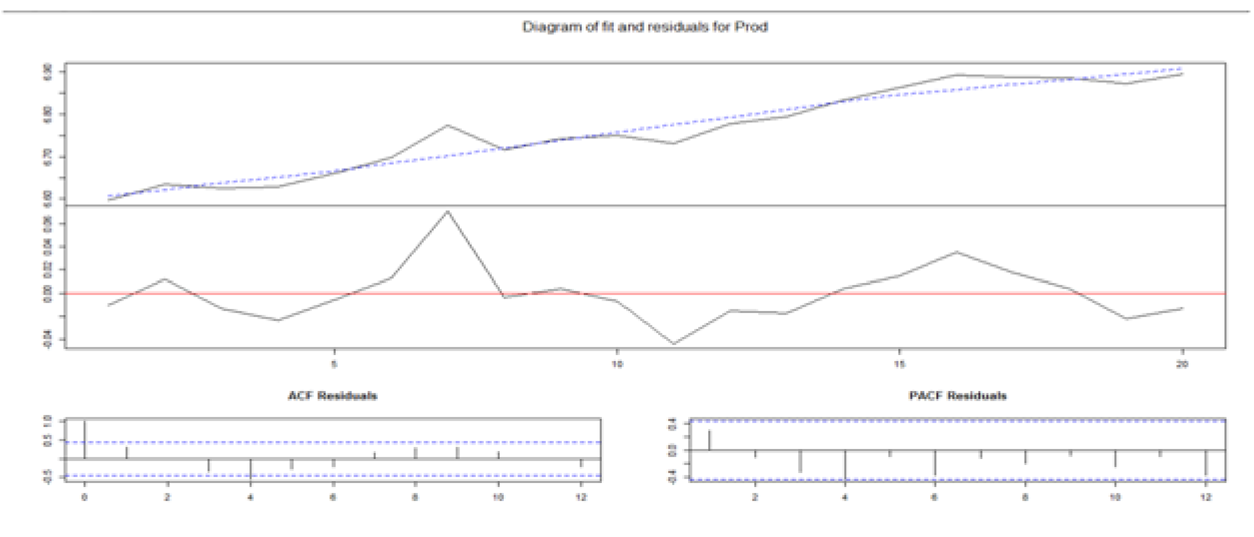

Figure 2.7: Diagram of fit and residuals for Production

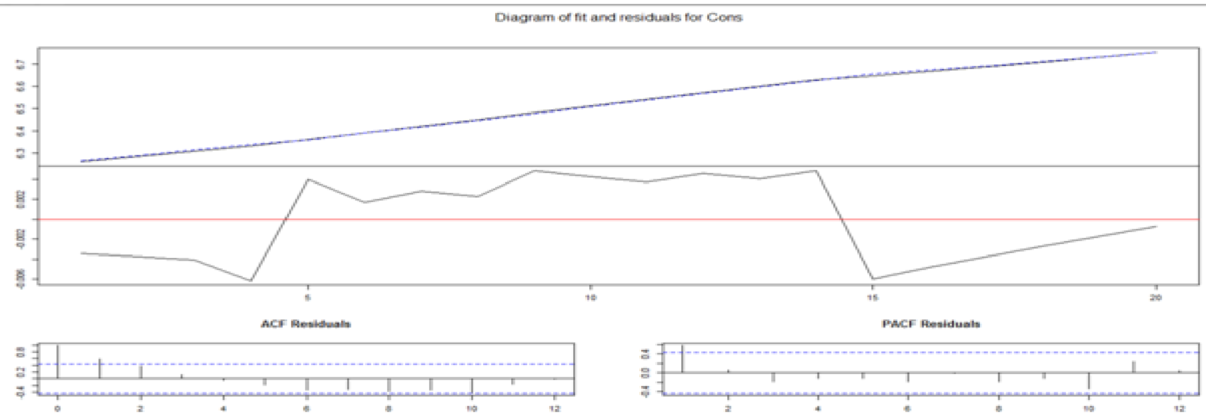

Figure 2.8: Diagram of fit and residuals for Consumption

The ACF and PACF plots of residuals corresponding to production and consumption in figures 2.7 and 2.8 look fine with ACF declining fast in both plots and PACF lying within the confidence limits in both cases. This is a clear sign of the stationary residuals. Next from the modeling perspective, it is customary to check if the residuals are white noise. The multivariate JB test was carried out to check if the residuals were normal. P value was found to be 0.0479 thereby proving that residuals were non-normal. Portmanteau test was used to check if the residuals were white noise. It checks if the PACF of the residuals is zero. The residuals were indeed found to be white noise with a p value of 0.4084.

The next step is to check for the causality between the variables. This is by far the most important aspect in VAR. It is a much stronger version of the relationship that is found in regression. There was no instantaneous causality between production and consumption but consumption was found to be granger causing production which was also clear from the model. On the other hand, production was not found to granger cause consumption which again was obvious from the model as production did not even affect consumption. Next we look at the impulse response plots to see how a unit shock in consumption affects production based on structuralVAR.

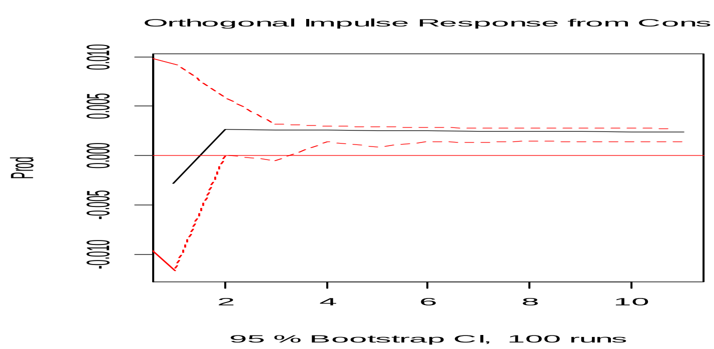

Figure 2.9: Orthogonal IRF from Consumption to Production

The IRF plot in figure 2.9 shows that a unit shock in consumption at lags 2 and 3 will have significant effect on current production. This shows that consumption two to three years before has a strong impact on the current level of production and hence Tea Board of India must frame policies to stimulate the demand for tea by improving its quality and promoting its generic brand.

Next we look at the prediction plot and the FEVD (Forecast error variance decomposition) plot.

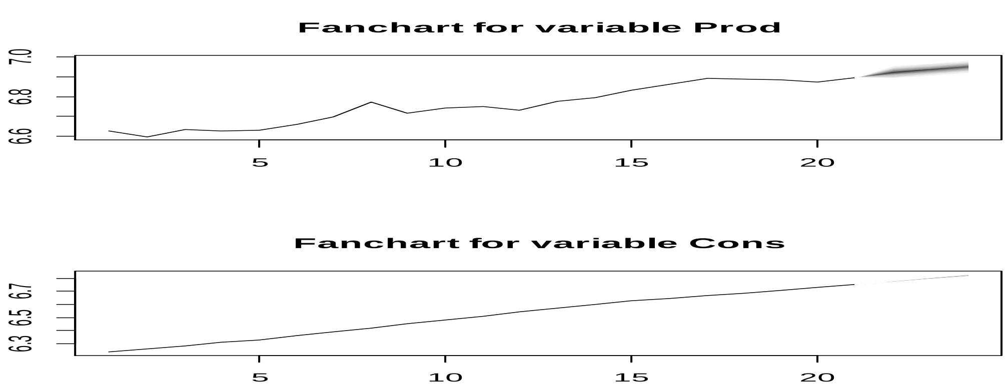

Figure 2.10: Prediction Chart for Production and Consumption

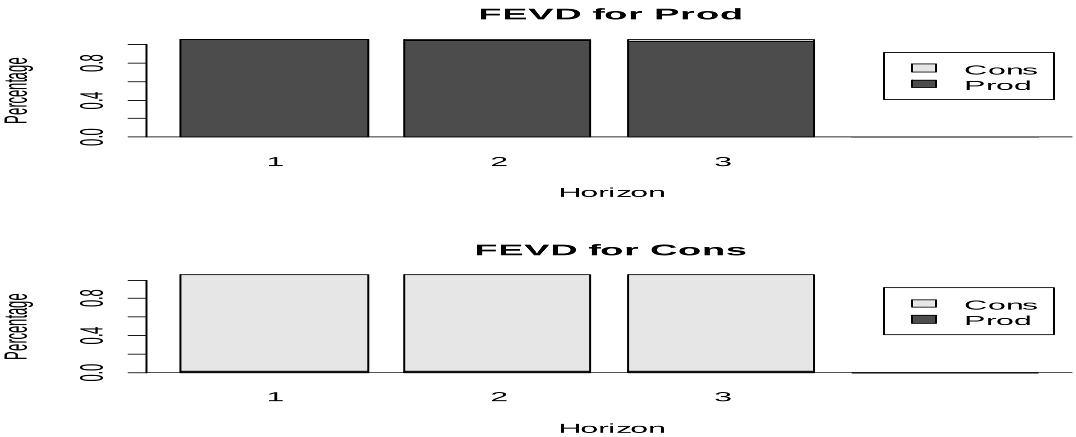

Figure 2.11: FEVD plots for Production and Consumption

The Fanchart (prediction plot) in figure 2.10 shows that both production and consumption will increase in the future. The FEVD plot in figure 2.11 shows that consumption does not play any part in contributing to the forecast of production in future. On the other hand, when consumption is forecasted, a very small percentage of error variance is contributed by production in all the three lags in future. But the percentage contributed is infinitesimally small and hence can be neglected as production does not cause or affect consumption.

D. Production and Number of Suppliers

Number of suppliers denotes the number of tea estates in India. The period of study was from 1991 to 2006 as data on number of suppliers was available only till 2006. Here in order to aid the modeling process, tea production was in terms of 1000 Kg and actual value of number of suppliers was taken. First we begin by visualizing the plot of number of suppliers to see how it changes across time.

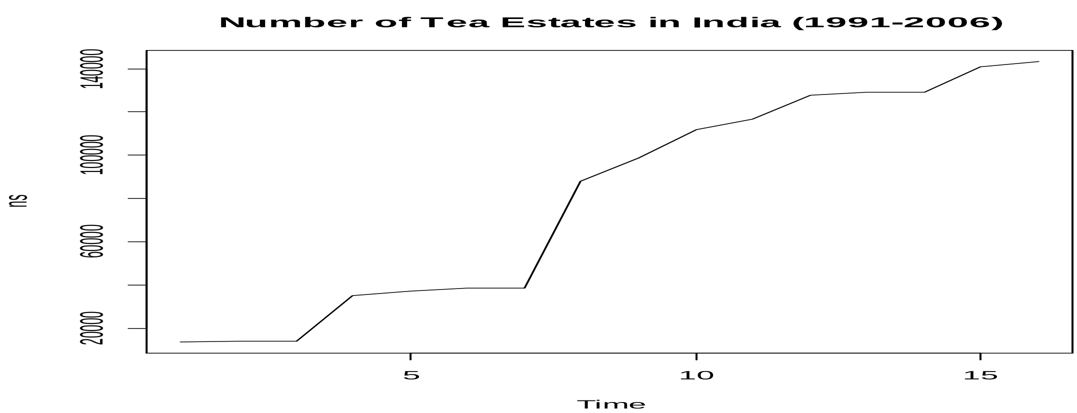

Figure 2.12: Time series plot of Number of Tea Estates in India

It can be seen from the time series plot in figure 2.12 that number of suppliers increase over time and hence presence of an increasing trend is clearly visible. We already saw an increasing trend in the production plot. Hence we can expect a direct correlation between the two variables. But only after modeling is done it can be understood as to how production is affected by number of suppliers at different lags.

The optimal order of the model was found to be four based on the all the four selection criteria viz. AIC, HQ, SC and FPE. The final VAR (4) model with only significant coefficients is shown below:

$Prod_t = 0.8117*Prod_{t-1} – 2.34*N_{t-1} + 0.8375*Prod_{t-2} + 0.9325*N_{t-2} + 1.2197*N_{t-3} – 0.5796*Prod_{t-4} + \varepsilon_{1t}$

Where, $Prod_t$ – Production of tea at time t

N_t – Number of Suppliers at time t

The model says that Production at time t will increase by 0.9325 units with a one unit increase in Number of suppliers at time (t-2) and by 1.2197 units with a one unit increase in Number of suppliers at time (t-3). This is understandable as we expect the production to go up with an increase in number of tea estates in India. But the complexity lies in interpreting the negative coefficient of Number of suppliers at time (t-1), which means that as the number of suppliers at time (t-1) increases, the production at time t will reduce. This is the reason why time series analysis is so useful. It helps in understanding how other variables affect the variable of interest at different lags. Here, the equation cannot be looked at separately but in its entirety. What it says is that production at time t depends on number

of suppliers at times (t-1), (t-2) and (t-3) in different ways and production at times (t-1), (t-2) and (t-4) in different ways. The increase or decrease in production can be ascertained only by calculating the production at time t and comparing it with that at time (t-1). Also the most important aspect that has to be kept in mind is that the above relationship between production and number of suppliers holds good only when there are no changes in other important variables like rainfall, temperature, consumption etc. But there will be changes in these variables over the year and let's say if rainfall is erratic in a particular year or consumption of tea comes down, the existing tea producers or tea estates will not produce as much as they would have in the previous year thereby leading to a drop in total production despite new tea estates coming up and contributing to some tea production.
To understand the exact relationship between production at time t and number of suppliers at time (t-1), both these variables were regressed and the following model was obtained.

$Prod_t = 7.427e{+}05 + 1.188 * N_{t-1} + \varepsilon_t$

Both the coefficients were found to be significant and the ANOVA of coefficient of N_{t-1} was also significantly different from zero. This shows that when only these two variables are taken, a positive relationship is found. On the other hand in the presence of other lags, the coefficient of N_{t-1} is negative thereby implying that the model in its entirety must be interpreted and not separately. Next, the model is plotted to see how well it approximates the actual values.

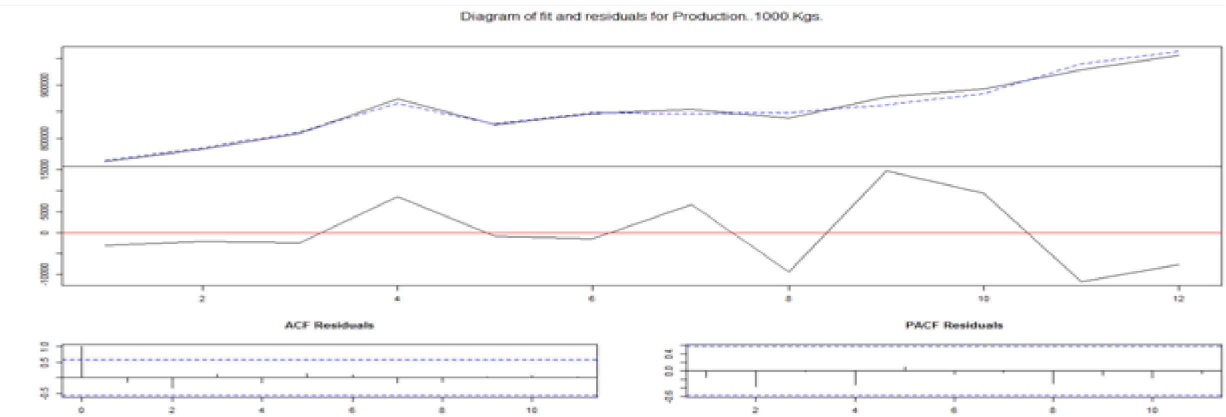

Figure 2.13: Diagram of fit and residuals for Production

The diagram of fit in figure 2.13 looks extremely good with most of the points predicted by the model also matching the actual values. The ACF and PACF plots also look fine. The residuals were tested for normality and white noise using Jarque Bera test and Portmanteau test respectively and they were found to be both normal and white noise with p values being 0.8364 and 0.4265 respectively.
The causality results indicate that number of suppliers granger causes production but the converse is not true which is understandable as supply depends on number of suppliers but a person who wants to enter the market would not look at supply but at other factors like demand, scope for profit making, entry barriers etc. Next we plot the impulse response function of number of suppliers on production as production is our variable of interest.

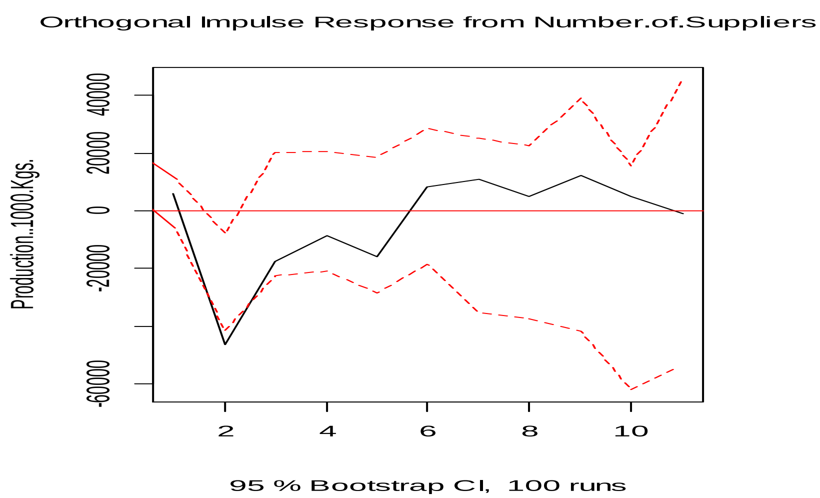

Figure 2.14: IRF plot of Number of Suppliers on Production

The upper limit of 95% Confidence interval cuts the 0 axis implying that the impact of a unit shock in number of suppliers on production is significant. Unit shock in number of suppliers at lag 2 seems to be having a significant impact on current production. This might be because of the significant exit barriers in tea manufacturing. Once an estate is started and tea bushes are grown which involves significant investment, the producers have to wait for 5 years for the bushes to become mature. It's not possible to remove investments from the estate before the gestation period. Hence a well planned decision will have to be made before investing in an estate or starting a new one.
Finally, we look at the prediction plot to see how production changes in future and FEVD plot to see how much of variance in the forecast of production is contributed by number of suppliers.

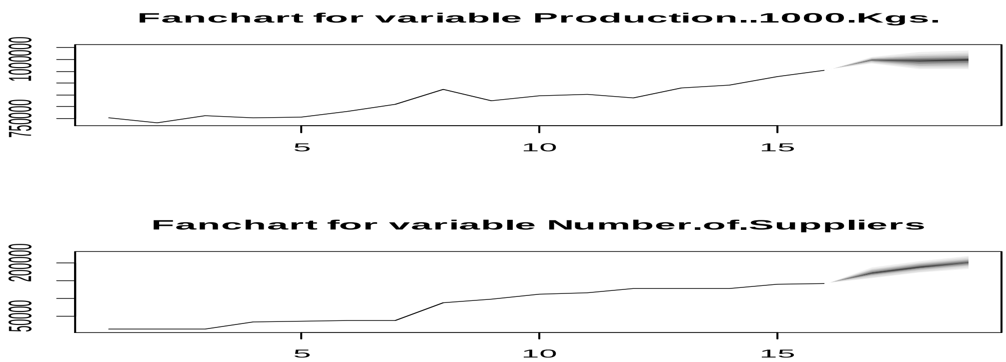

Figure 2.15: Prediction plots of Production and Number of Suppliers

The prediction plot shows that production remains more or less constant in the next three years while number of suppliers increases.

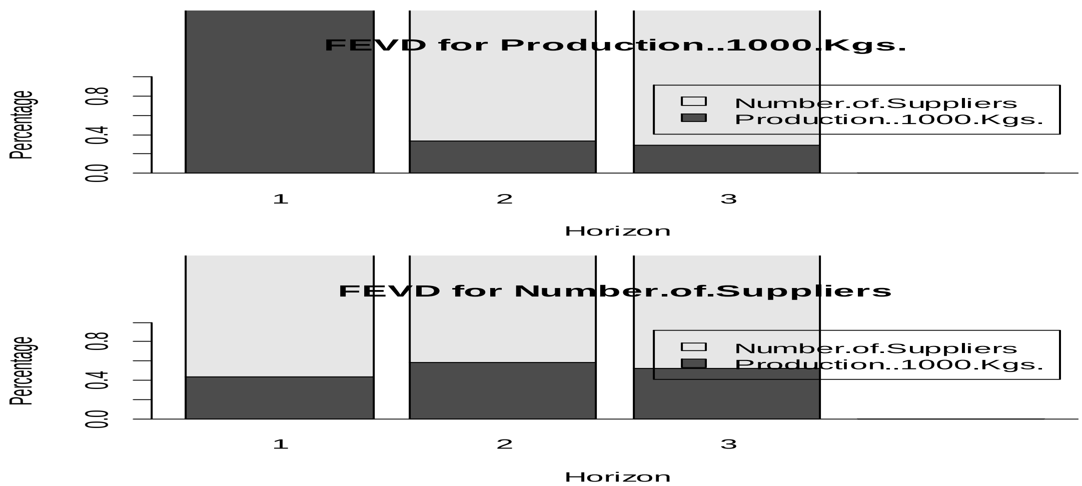

Figure 2.16: FEVD plots of Production and Number of Suppliers

FEVD plot for production shows that in lags 2 and 3, number of suppliers significantly contributes to variance in forecast error of production.

E. Production and Labour

Production in 1000 Kg is modeled with Average number of laborers employed in tea sector for the period (1991-2005). Yearly data was used for modeling the variables. The analysis is started by first visualizing the labor plot and seeing how labor varies across time.

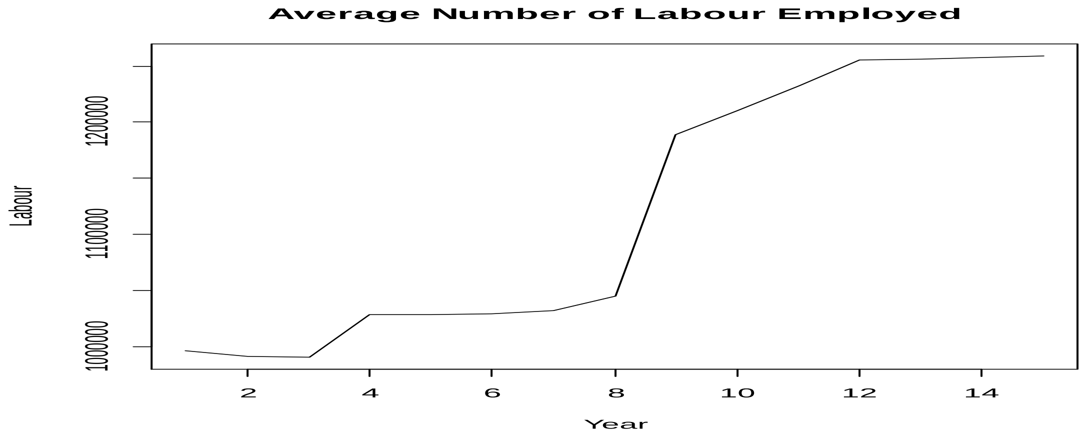

Figure 2.17: Time series plot of Labor

The labor plot shows an increasing trend with some fluctuations. The optimal order of the model was found to be 4 based on AIC, HQ and SC. The final model is as shown below:

$Prod_t = 3.507\ e^{-1} * Labor_{t-2} + 4.520\ e^{5} + \varepsilon_{1t}$

The final model says that production at time t will increase by 0.3507 units with a unit increase in labor at time (t-2). Labor is a very important input for production and we expect a direct relationship between supply and its inputs. For this reason, the model is understandable.
Unit root tests were conducted and found that production was I (2) and labor was I(3). Hence cointegration cannot be performed. The residuals were checked for normality and white noise using multivariate Jarque Bera test and Portmanteau test and they were found to be both normal and white noise with p values being 0.2821 and 0.4312 respectively. The causality results indicate the presence of instantaneous causality between production and labour. Also production is found to be granger cause labour. The IRF plot of labour on production is shown in figures 2.18:

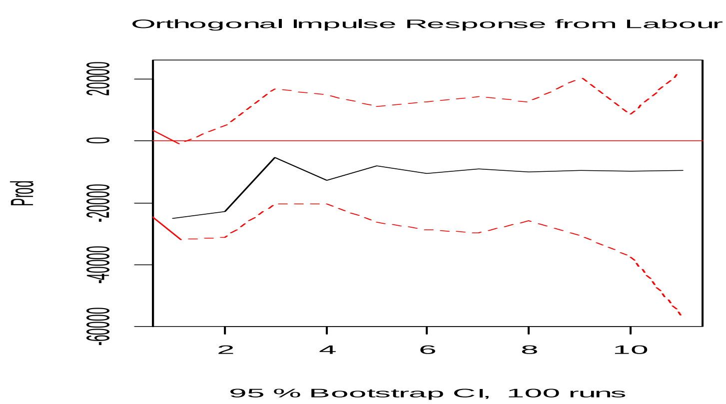

Figure 2.18: IRF plot of Labour on Production

In figure 2.18, the 95% bootstrap confidence intervals do not touch the 0 axis implying that a unit shock in labor does not have any significant impact on current level of production.
Finally, the prediction plot and FEVD plot are visualized to see how production changes in future according to the model.

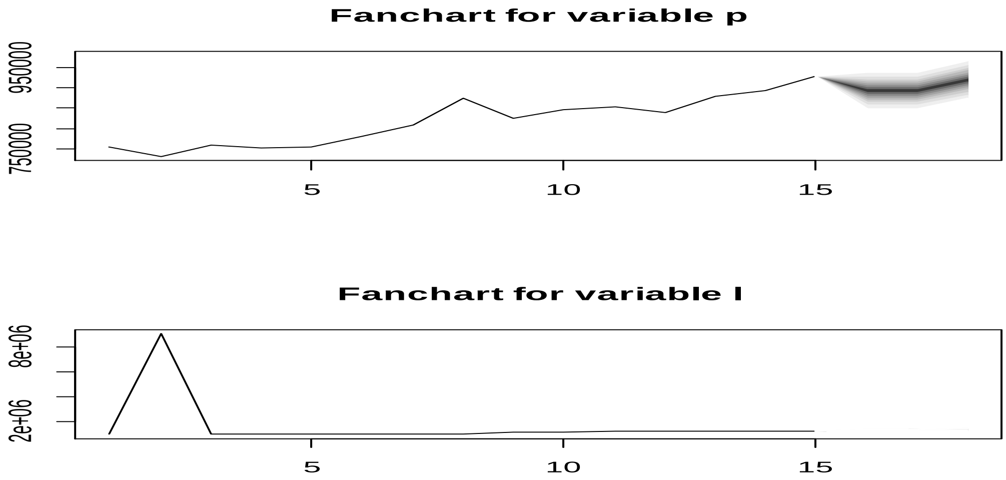

Figure 2.19: Prediction Plots of Production and Labor

Production decreases and then increases in the next three years according to the model.

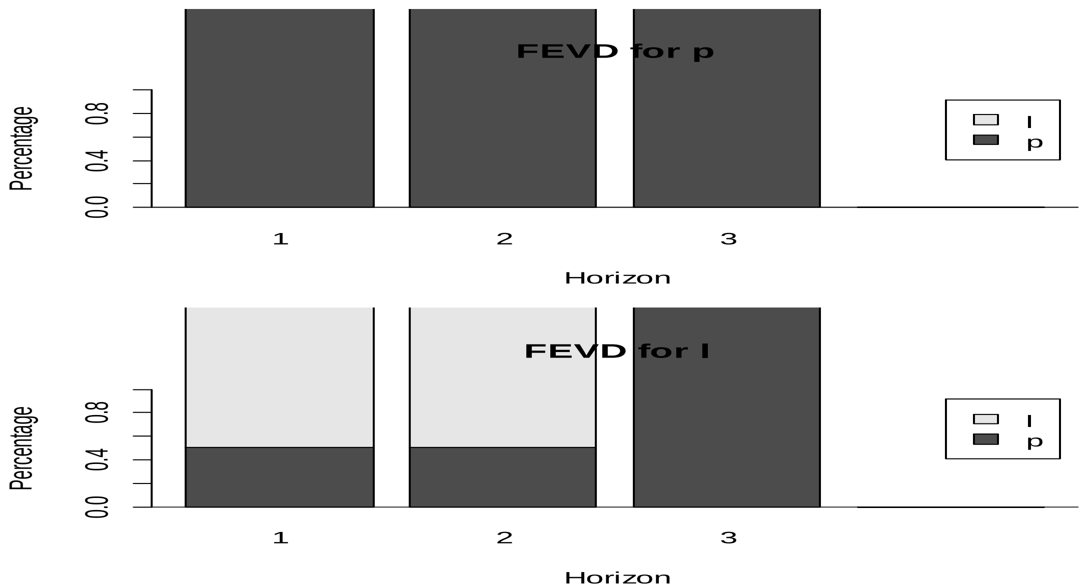

Figure 2.20: FEVD plots of Production and Labor

Labor doesn't contribute to variance of forecast error in production while production contributes to variance in forecast error in labor in the next two years.

F. Production and Price

Monthly data from 1991 to 2005 was used to model production in 1000 Kg and auction price. We expect a positive relationship between production and price as producers will produce more when they see a price increase.

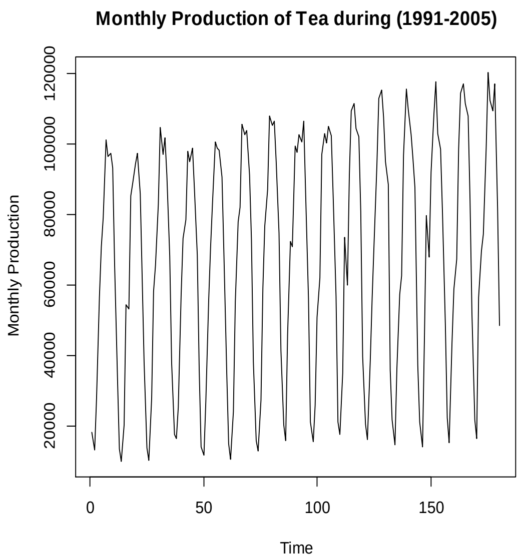

Figure 2.21: Monthly Production plot

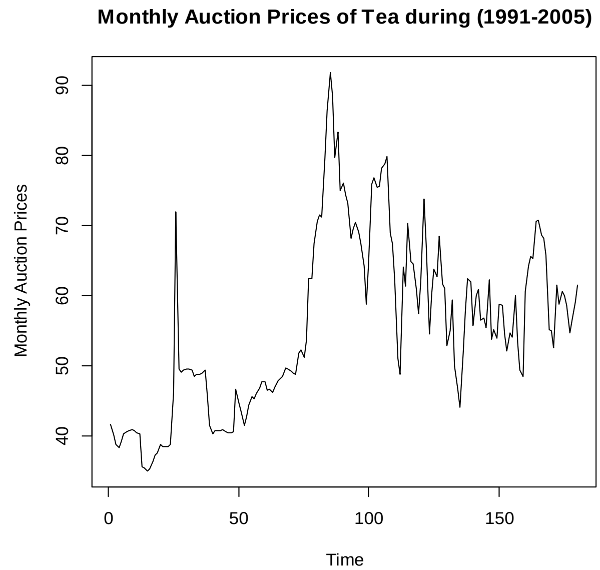

Figure 2.22: Monthly Auction Prices plot

The production plot shows that seasonality is present with increases in June, July and August of every year. Price plot indicates the presence of volatility.

The optimal order of the model was found to be 4 using all the four criteria – AIC, HQ, SC and FPE. The final VAR (4) model is as shown below:

$$Prod_t = 1.009*Prod_{t-1} - 2.431\ e^{-1}*Prod_{t-2} + 5.986\ e^{2}*Price_{t-2} - 4.071\ e^{2}*Price_{t-3} - 3.305\ e^{-1}*Prod_{t-4} + 2.769\ e^{4} + \varepsilon_{1t}$$

The final model says that production at time t increases with increase in auction price at time (t-2) and decreases with increase in price at time (t-3). The fact that there is a positive relationship between production at time t and price at time (t-2) is understandable as producers will produce more when they see increasing prices. But production increase is not because of increasing the area. In the short run acreage cannot be changed. What can be done is replanting, replacement planting, extensions (extending further to existing land for possible investments in future), etc. But even these will have an effect on total production only after the gestation period of 5 years when the crops become mature. But production per unit area or yield can be increased by adoption of improved cultural practices like manuring, intensive cultivation via proper use of fertilizers and pesticides, timely pruning of tea bushes and adopting good plucking style. Hence production can be increased or decreased by producers in this way based on price signals. But there is a negative relationship between production at time t and price at time (t-3) which might be because of other factors like poor rainfall or other factors which are beyond the control of producers. Also the model has to be understood in its entirety.

The residuals were checked for normality and white noise and they were found to be white noise and non-normal with p values for Jarque Bera test and Portmanteau test being $2.2*10^{-16}$ and 0.3297 respectively. Causality results suggest the presence of instantaneous causality between production and prices implying that production at time t is caused by price at time t and vice versa. Also prices were found to be granger causing production. The IRF plot is shown in figure 2.23.

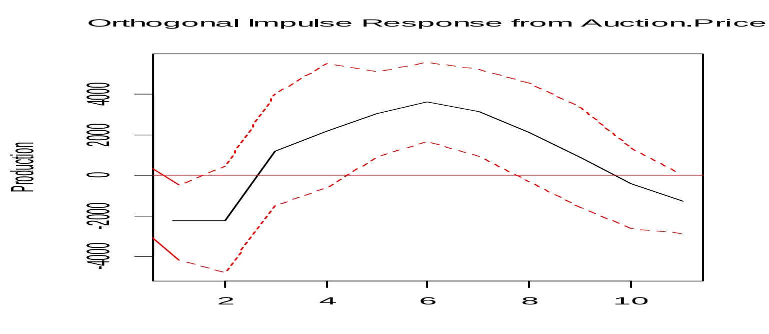

Figure 2.23: IRF plot of Price on Production

The IRF plot of price on production in figure 2.23 shows that unit shocks in price at lags 5, 6 and 7 seem to have significant impact on current level of production. Hence it’s very essentially to reduce the volatility in prices and keep them stable.

Finally, the prediction and FEVD plots are visualized to see how production and price change in future.

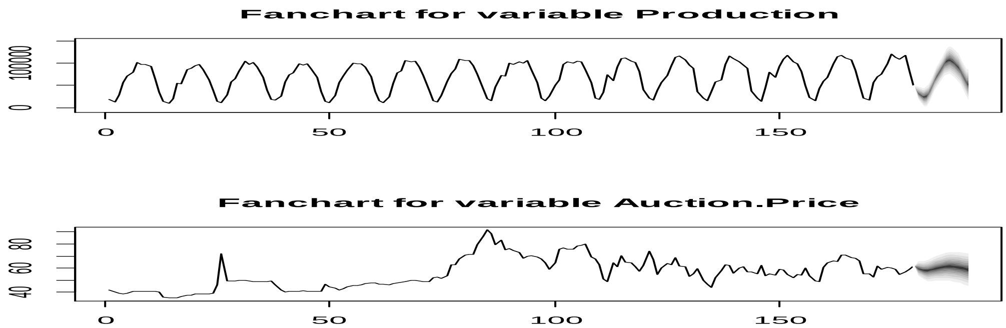

Figure 2.24: Prediction plots of Production and Price

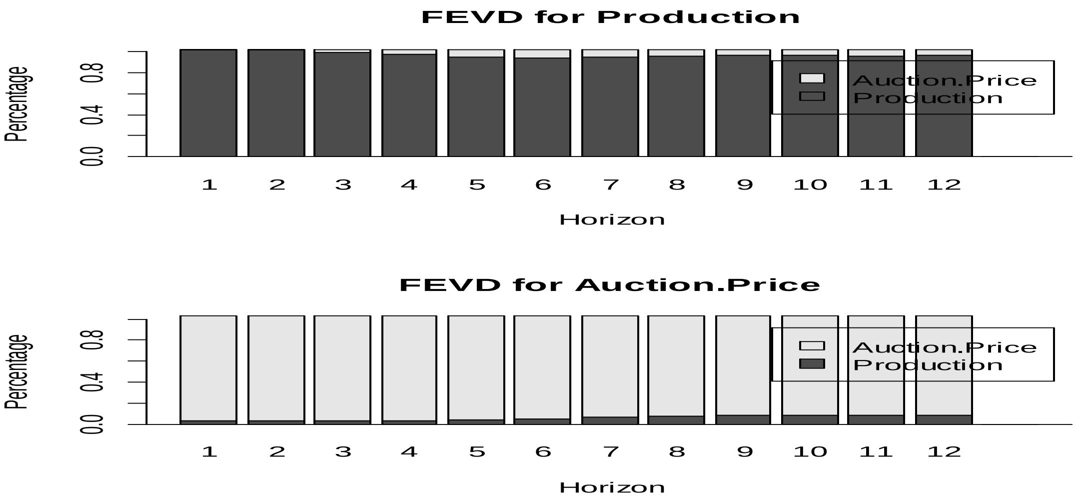

Figure 2.25: FEVD plots of Production and Price

The FEVD plots show that the contribution of price to variance of forecast error in production is small and same is true with price as well. Twelve months ahead forecasts are shown in fanchart.

G. Production and Age of Tea bushes

Age of tea bushes is one of the most important factors affecting tea production as only mature tea bushes in the age category of 5-50 years contribute to yield. If the age of tea bushes crosses 50 years, its yield capacity will come down and hence will have to be uprooted for planting new crops.

In the modeling process, We have taken the proportion of area of tea bushes in the age group of above 50 years to the total area to be the 2nd variable and production (in 10^8 units) to be the 1st variable which is our variable of interest. Yearly data from 1991 to 2004 was used to model the two variables.

First the raw time series plots are visualized to see how the variable behaves.

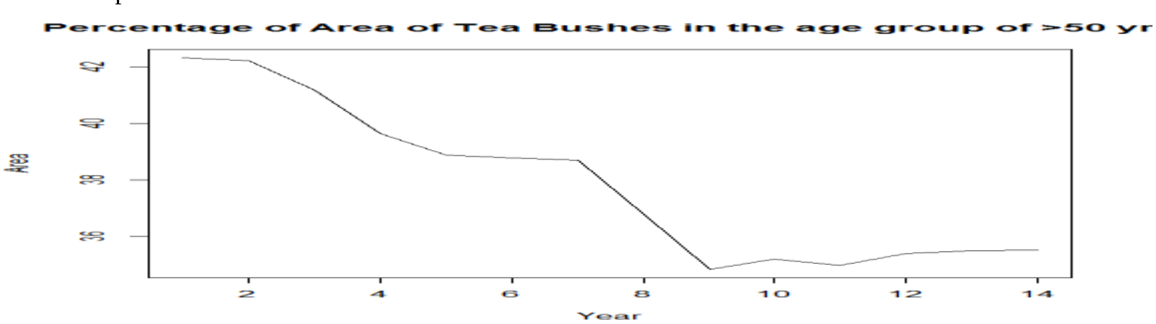

Figure 2.26: Time series plot of Percentage of Area of tea bushes of age > 50 yrs

The plot of 2nd variable in figure 2.26 shows a decline over time and production plot shows an increase as seen already and hence one can naively expect a negative relationship.

The optimal order of the model was found to be one according to all the four criteria – AIC, HQ, SC and FPE. The final VAR (1) model is as shown below:

$Prod_t = -0.165*Area_{t-1} + 14.43271 + \varepsilon_{1t}$

The second part shows how production affects area but we are not interested in that as our variable of interest is production and moreover area in the age group of > 50 years is not dependent on supply but on price. When the prices increase, producers would want to produce more and hence invest for the future which is done by uprooting old tea bushes and planting new seedlings.
The final model says that production at time t reduces when the proportion of area in the age group of above 50 years to the total area increases which is true as we saw earlier.
The residuals of the final model were found to be both normal and white noise using Jarque Bera test and Portmanteau test whose p values were 0.4499 and 0.1215 respectively. The causality results are not positive. The IRF plot of area on production is shown in figure 2.27.

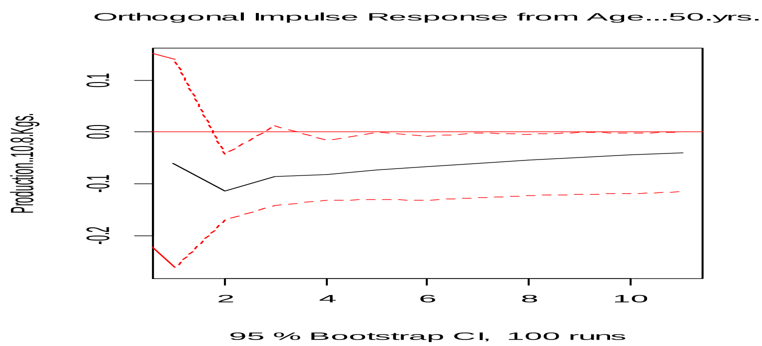

Figure 2.27: IRF plot of Proportion of Area on Production

The IRF plot in figure 2.27 shows that unit shocks in percentage of area of tea bushes in the age group of above 50 years to the total area at lags 2 and 4 have significant impact on current level of production. This indicates that age of tea bushes is a very important factor that affects tea production.

Finally, the prediction and FEVD plots are visualized to see how the variables change in future.

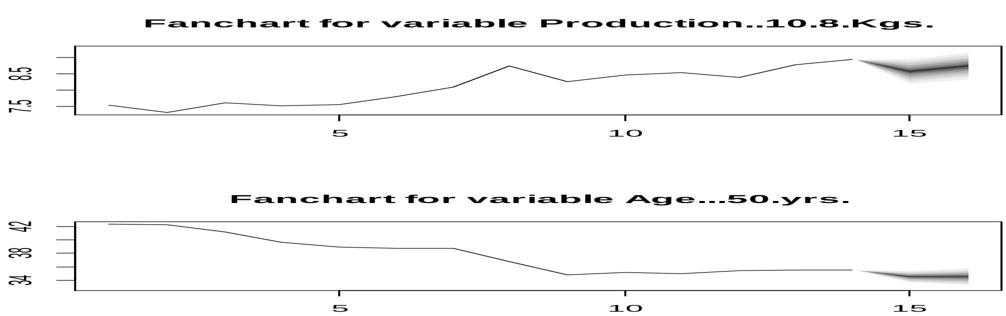

Figure 2.28: Prediction plots of Production and Percentage area of tea bushes of age > 50 yrs

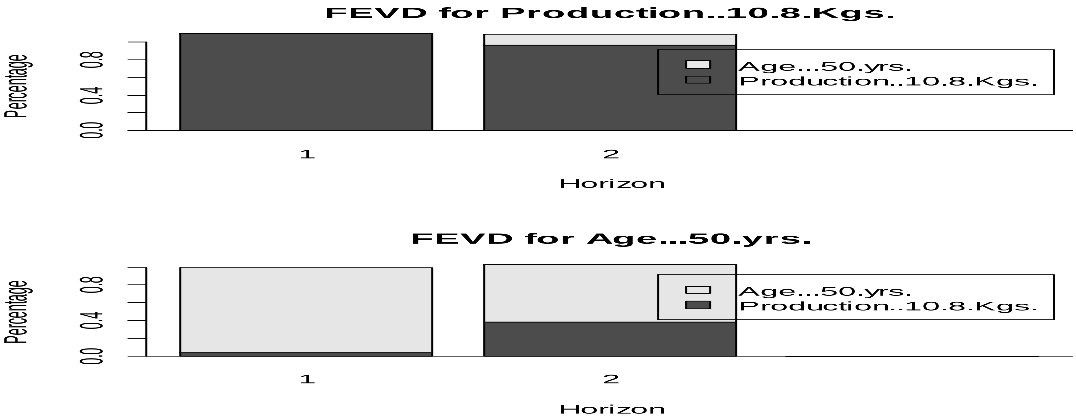

Figure 2.29: FEVD plots of Production and Percentage area of tea bushes of age > 50 yrs

Production seems to decrease and then increase in the next two years. The FEVD plot shows that the proportion of area contributes about 10-20% of variance in forecast error of production which is understandable as proportion of area causes production.

H. Production, Rainfall and Temperature

The monthly plot on production showed the presence of seasonality which means that in some months in a year, production would be high, while it will be low in other months. Since data on soil temperature was not available, production and rainfall were modeled for three different seasons viz. Monsoon (June-September), Post Monsoon (October-December) and Pre Monsoon (March-May). Yearly data for the period (1991-2006) was used for this purpose.
In Monsoon period, production did not show any correlation with rainfall and hence no stable model could be developed.

I. Production and Rainfall in the Post Monsoon Period

Production (in 1000 Kg) and Rainfall (in mm) were modeled in the post monsoon period using VAR. First the time series plots are visualized to understand the behavior of both the variables.

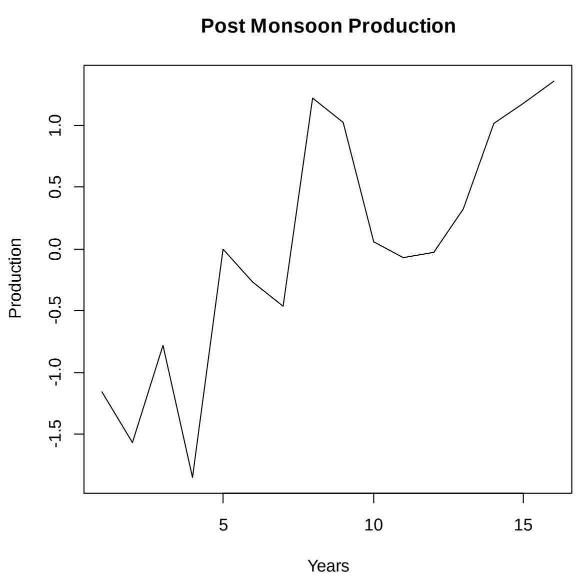

Figure 2.30: Time series plot of Production in Post Monsoon period

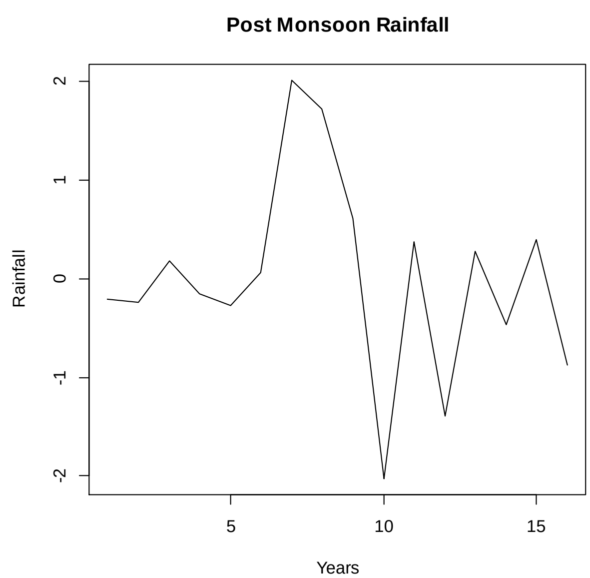

Figure 2.31: Time series plot of Rainfall in post Monsoon period

Production shows an increasing trend while rainfall doesn't show any trend. The optimal order of the model was found to be 2 based on the following criteria – AIC, HQ, SC and FPE. The final VAR (4) model is as shown below:

$Prod_t = 334.00157*Rainfall_{t-1} + 0.83878*Prod_{t-2} + \varepsilon_{1t}$

The final model says that production at time t depends only on production at lag 2 and rainfall at lag 1. The coefficient corresponding to rainfall at lag 1 is positive implying that as rainfall at time (t-1) increases, production at time t increases which is understandable as we expect a positive relationship between production and rainfall.
The residuals of the final model were found to be both normal and white noise with p values of Jarque Bera test and Portmanteau test being 0.6716 and 0.2312 respectively. Causality results were not found to be positive. The IRF plot of rainfall on production is shown in figure 2.32.

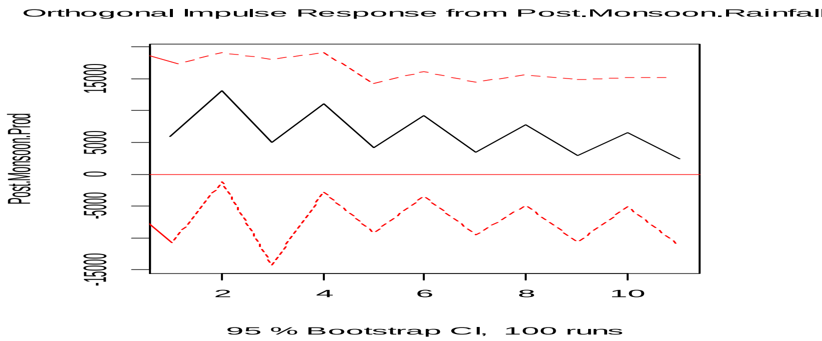

Figure 2.32: IRF plot of Rainfall on Production

Since the 95% bootstrap confidence intervals don't touch the 0 axis, the impact of unit shock in rainfall on production is not significant.
Finally we look at the prediction and FEVD plots to see how the variables behave in future.

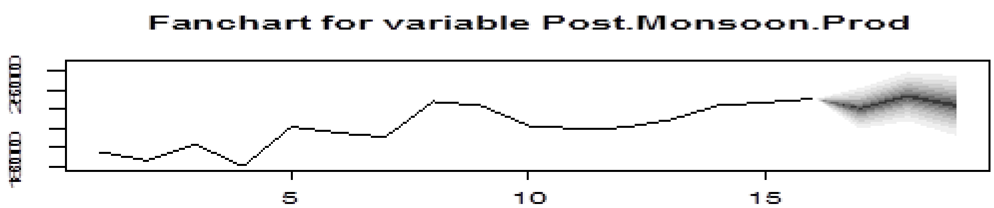

Figure 2.33: Prediction plot of Production

The prediction plot shows that production decreases initially and then increases in the next three years.

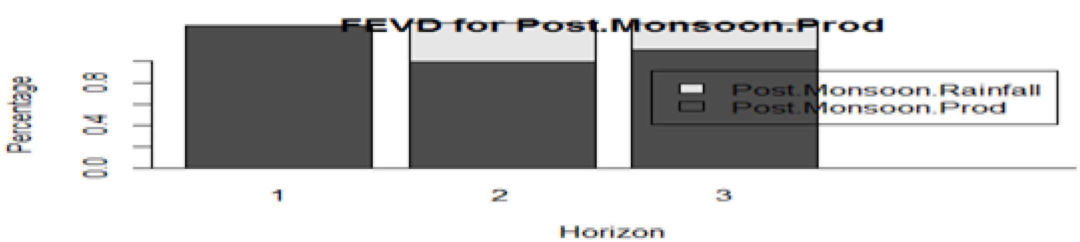

Figure 2.34: FEVD plot of Production

The FEVD plot shows that rainfall contributes about 20% to the variance of forecast error in production at lag 2 and about 10% at lag 3. This is understandable as rainfall at lag 1 affects production and hence its forecast will depend on rainfall.
Note that we are just interested in the final model and understanding the dynamics between variables and prediction is not the objective. This is because production should be forecasted using a model that contains all significant factors or variables as only then an accurate forecast could be obtained. But in all the discussed pair wise cases, we would just like to test how the independent variable considered affects production's forecast and error variance.

J. Production and Rainfall in the Pre Monsoon Period

Production (in 1000 Kg) and Rainfall (in mm) were modeled in the pre monsoon period using VAR. The final result of the model could not explain the dynamics and relationship between production and rainfall, as neither production nor rainfall depended on the other variable.
The final model was of the form given below:
$Prod_t$ = Constant

$Rainfall_t$ = Constant
We, thereby conclude that there is no significant correlation between production and rainfall in the pre monsoon period and hence rainfall does not affect production in this period.

K. Production and Coffee Prices

Aggregate annual tea production (in Million Kg) is modeled with domestic average price of Robusta Coffee (in Rs/Kg) using VAR. Coffee is a substitute for tea and hence we expect an inverse relationship between supply of tea and coffee prices. The data period is from 1994 to 2011. The time series plots of domestic coffee prices and production are shown in figures 2.35 and 2.36 respectively.

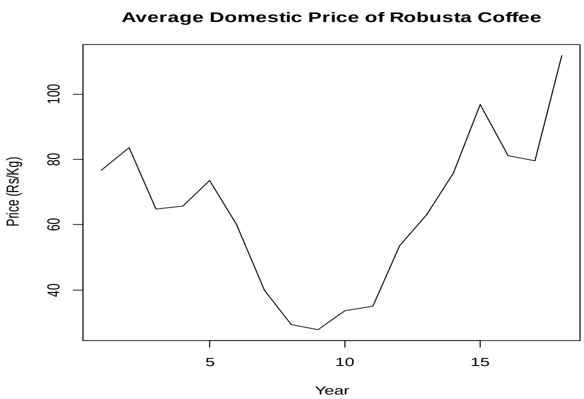

Figure 2.35: Time series plot of Domestic Coffee Prices

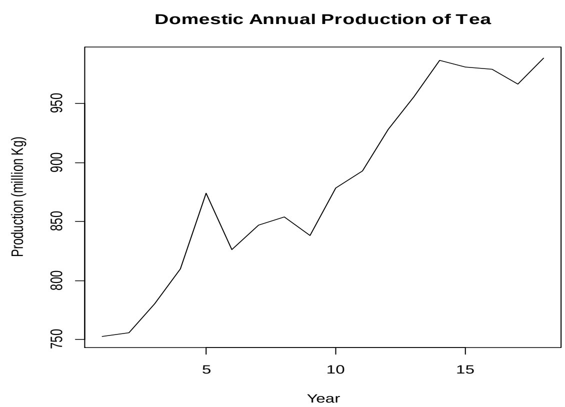

Figure 2.36: Time series plot of Domestic Production of Tea

Production as before shows an increasing trend while coffee prices initially decreases and then increases. The optimal order of the model was found to be 4 based on AIC, HQ, SC and FPE. The final VAR (4) model with only significant coefficients is as follows:

$Prod_t = 552.75147 + 1.18016*Price_{t-1} + 0.45119*Prod_{t-4} – 1.67427*Price_{t-4} + \varepsilon_{1t}$
$Price_t$ – Domestic Coffee Price at time t
The final structural VAR model says that a unit increase in coffee prices at lag 1 will increase tea production by 1.18 units while a unit increase in coffee prices at lag 4 will decrease tea production by 1.67 units. Economics tells us that there is an inverse relationship between supply of particular goods and price of substitutes. Given this a positive coefficient for price at lag 1 does not concur with the known fact. But as mentioned before the coefficients should not be looked at separately but the model should be interpreted in its entirety. When coffee price at lag 1 was regressed with production, a negative coefficient of 0.67 is obtained which concurs with theory. Hence the final VAR model says that in presence of price and supply at lag 4, there seems to be a positive relationship between supply and price at lag 1.
The residuals of the final model were found to be both normal and white noise with p values of Jarque Bera test and Portmanteau test being 0.7006 and 0.2521 respectively. There seems to be instantaneous causality between tea production and coffee prices although granger causality fails. The IRF plot of coffee prices on tea production is shown in figure 2.37.

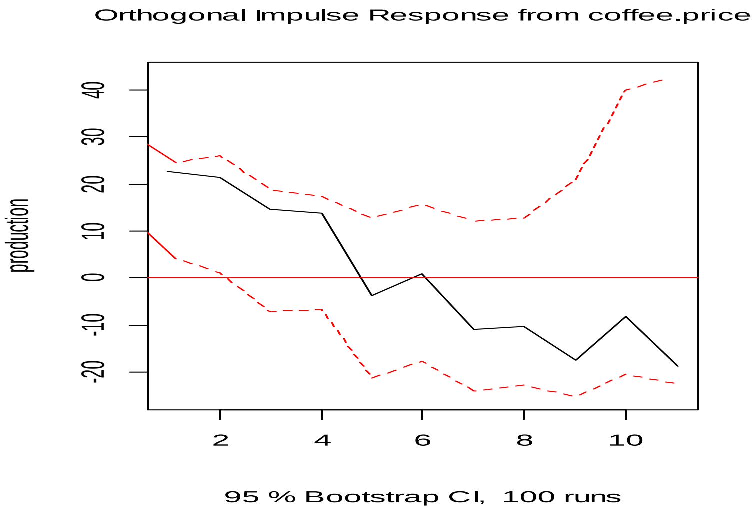

Figure 2.37: IRF plot of Coffee Prices on Tea Production

The plot says that a unit shock in domestic coffee price at lag 2 has a significant impact on current tea production. Finally we look at the prediction and FEVD plots to see how production changes in future because of coffee prices.

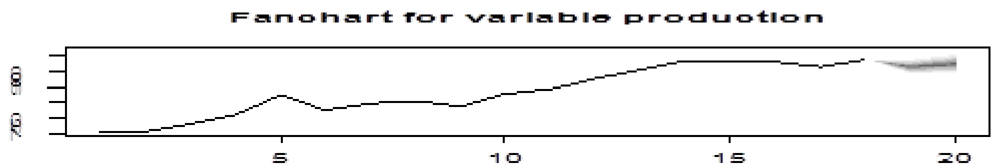

Figure 2.38: Prediction plot of Production

Tea production according to the structural VAR model shows a decline in the next two years.

Figure 2.39: FEVD plot of Production

Coffee price does not contribute to the variance of error forecast of production. This is a little surprising as coffee prices affect tea production according to the model.

Finally, it is of utmost importance to mention all variables that were not found to be affecting production. They include rainfall in monsoon and pre monsoon period, area under plucking, GDP, revenue through cess, bearing area and relative auction price of tea. Area under plucking is actually an important variable but may be because of lack of sufficient data points, stable model wouldn't have resulted. The same can be said about revenue through cess, as well. Also there seems to be not much correlation between tea production and relative price of tea which is the ratio of actual to expected tea price. This again can be attributed to lack of sufficient data points.

VII. DATA AND METHODOLOGY

Tea industry in the past five years has experienced increase in auction prices owing to strong demand from local and overseas buyers. On the other hand, annual production has not shown any significant increase. This study focuses on modeling of production and auction prices of tea in India. Market integration and price transmission between selected auction and retail markets of tea in India are analyzed. Price transmission between domestic and international auction markets of tea is examined empirically. The broad objectives of the study as mentioned in chapter one are:

- Identifying factors affecting tea production in India
- Modeling of Annual tea production with the identified factors
- Finding reasons for why or how some factors, if any, did not show any effect on production

These major objectives were dealt with separately in subsequent chapters. Factors affecting annual tea production were identified and modeled in chapter two. Possible reasons for some factors not showing correlation with production were discussed. The following variables were assumed to be affecting aggregate tea production in India from literature - Area under cultivation of Tea, Domestic Consumption, Price, Rainfall, Temperature, Age of Tea Bushes, Labour, Area under plucking, GDP at Market prices, Revenue through Cess and Number of Suppliers. A pair wise analysis was done using VAR as the methodology and the findings that emerged from empirical analysis are as follows:

- VAR (1) model was developed between production and consumption in which production depended on consumption at lag 1 with a positive coefficient while consumption depended only on its own lag. Consumption was found to be granger causing production with the IRF plot showing that the impact on production caused due to a unit shock in consumption is felt for a very long period.
- VAR (4) model was developed between production and number of suppliers in which production depended on number of suppliers at lags 1, 2 and 3 and on its own lags. The dynamics was found to be complex with the coefficient corresponding to number of suppliers at lag 1 being negative and the other two coefficients being positive. Here, the number of suppliers denotes the number of tea estates in India and hence we expect the production to rise with increase in number of suppliers. We also proved that there is a positive relationship between production at time t and number of suppliers at time (t-1) and hence VAR model will have to be interpreted in its entirety. Number of suppliers was found to be granger causing production with the IRF plot showing that the impact on production due to a unit shock in number of suppliers will be significant and also will be felt for a long period.
- VAR (4) model was developed between production and average number of labor employed in the tea industry in which production depended on labor at lag 2 with a positive coefficient and labor depended on production at lags 2 and 3 with both being positive coefficients. The causality results are not positive while IRF plots show that unit shocks in either variable will have significant impacts on the other variable for many lags.
- When production was modeled with auction prices using yearly data, no correlation was found between them. When they were modeled with monthly data from 1991 to 2005, VAR (4) model was developed in which production depended on price at lags 2 and 3 with the coefficient corresponding to price at lag 2 being positive and the coefficient corresponding to price at lag 3 being negative while price depended on production at lag 4 with the corresponding coefficient being negative. Instantaneous causality was found to be present between production and price and price was found to be granger causing production. The IRF plot of price on production showed that the impact on production due to a unit shock in price would be felt for about eight months. The same was found to be true in the case of IRF plot of production on price.
- VAR (1) model was developed between production and proportion of area of tea bushes in the age group of above 50 years to the total area in which production depended on the second variable at lag 1 with the coefficient being negative. The causality results were not positive while the IRF plot of the second variable on production showed that the impact due to a shock in the second variable on production is slightly significant.
- VAR (4) model was developed between production and rainfall in the post monsoon period (October-December) in which production depended on rainfall at lag 1 with the corresponding coefficient being positive implying that production would increase with increase in rainfall. Causality results were not positive and IRF of rainfall on production was also not significant.

The variables that were initially assumed to affect production but did not show any correlation with it were rainfall in monsoon and pre monsoon period, area under plucking, GDP and revenue through cess. One reason for this could be because of lack of sufficient data points. Tea cess is a tax levied by the central government. Revenue through cess (in crores) is the total amount that government of India through Tea Board got by imposing cess on tea. It will be included in the auction prices of tea sold through public auctions. Revenue from cess can increase either due to an increase in total quantity produced or due to an increase in cess levied per kg of tea. The analysis showed that this did not have any correlation with the total supply of tea in India. Again this could be because of the same reason mentioned above.

VIII. LIMITATIONS

In production modeling, bivariate analysis has been carried out which is devoid of partial relationships. This is because of lack of sufficient data points. Bivariate models can only help in understanding the marginal effect of other variables on the variable of interest.

ACKNOWLEDGMENT

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