COMPARISON OF PERFORMANCE AND ITS DETERMINANTS OF COFFEE AND CARDAMOM IN SOUTH INDIA: A STATISTICAL ANALYSIS

by

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(2017-19-005)

THESIS
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2019

DECLARATION

I, hereby declare that this thesis entitled **"Comparison of performance and its determinants of coffee and cardamom in South India: A statistical analysis"** is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar title of any University or Society.

Place: Vellayani,
Date: 16/08/2019

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MURUGESH HUCHAGOUDAR

Affectionately dedicated

to

my beloved

Parents & Sisters

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LIST OF ABBREVIATIONS USED

ADF	Augmented Dickey-Fuller
AIC	Akaike Information Criterion
ARCH	Autoregressive Conditional Heteroscedasticity
BIC	Bayesian Information Criterion
CAGR	Compound Annual Growth Rate
CRS	Cardamom Research Station
CV	Coefficient of variation
et al.	Co-workers
GARCH	Generalized Autoregressive Conditional Heteroscedasticity
GOI	Government of India
HYP	High Yielding Varieties
ICO	International Coffee Organisation
ICRI	Indian Cardamom Research Institute
KAU	Kerala Agricultural University
LM	Lagrange's Multiplier
LPG	Liberalisation Privatisation and Globalisation
OLS	Ordinary Least Square
RARS	Regional Agricultural Research Station
RH	Relative Humidity
SE	Standard Error
UAE	United Arab Emirates
USA	United States of America
VIF	Variance Inflation Factor

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LIST OF ABBREVIATIONS AND SYMBOLS

%	Per cent
°C	Degree Celsius
ha	Hectare
i.e.	that is
kg ha^{-1}	Kilogram per hectare
m	Meter
mm	Millimetre
Rs kg^{-1}	Rupees per Kilogram

Introduction

1. INTRODUCTION

Coffee and cardamom are the major plantation crops, mainly grown in South Indian states Kerala, Karnataka and Tamil Nadu. Moreover, these two crops play major role in the livelihood of farmers, farm households and agricultural labourers by providing income and generating employment opportunities to the agricultural labourers. Both coffee and cardamom are export oriented commodities and have importance of foreign exchange in the economy (Nair, 2006).

1.1 COFFEE

Coffee is the world's supreme brewed drink. Millions of people around the globe can't start a day without a cup of coffee in the morning. Coffee is not only a drink for taste and flavor, it contains stimulant 'caffeine' which stimulates the brain of the people and feels them refreshing. Coffee contains high level of antioxidants as compared to other common beverages. It is the second most traded commodity in the world after crude oil and most valued commodity exported by several coffee growing countries in the world (Mohan and Love, 2004)

Brazil is the highest producer of coffee in the world followed by Vietnam, Colombia, Indonesia, Honduras Ethiopia, India, Uganda, Mexico, Guatemala, etc. One among the largest producer of coffee in the world, India stands on seventh position for coffee production (ICO, 2018). It is one of the important commercial crop for the tropics.

Botanically coffee belongs to the family *Rubiaceae.* This family includes species of trees, shrubs, and herbs which are widely grow in tropical and sub-tropical regions throughout the world. The coffee plant is the native of Kaffa region's tropical rain forests of Ethiopia in Africa. Coffee has been a major export earning commodity of several coffee growing countries in the world. At present coffee is cultivated in more than 70 countries, mainly in the equatorial regions of Central and South America, Southeast Asia and Africa.

1.1.1 History of coffee in India

Coffee was introduced in India during the 17th century by an Indian Sufi saint Baba Budan, who first brought the coffee beans from Yemen to India. These beans were raised in the hills of Chikmagalur district in Karnataka which are now called as Baba Budan hills. Therefore, Baba Budan hills were known as the birth place and origin of coffee in India (Yashavanth, 2010). Since then coffee cultivation extended to Kodagu and other districts of Karnataka, later neighboring states like Kerala, Tamil Nadu *etc.*

1.1.2 Production of coffee in India

India is the only country which grows all of its coffee under shade. Indian coffee is one of the most extraordinary beverages, with high stimulating intensity. Indian coffees are not too acidic, which are mild; possess fine aroma and exotic full-bodied taste (Yashavanth, 2010).

Commercial cultivation of coffee in India started in the year 1820's even though coffee was introduced in the 17th century. The Western Ghats in south India forms the backbone of India's coffee industry. Coffee is mainly cultivating in three regions of India such as traditional coffee growing region covering Karnataka, Kerala and Tamil Nadu, followed by non-traditional areas which include Andhra Pradesh and Orissa in the eastern coast and the third region consists of North-Eastern states. Coffee growing regions of India have diverse climatic conditions, which are suited for growing of different varieties of coffee. India cultivates both the well-known and commercially important species of coffee, *viz.*, *Coffea arabica* (Arabica coffee) and *Coffea canaphora* (Robusta coffee). The areas with high altitudes are more suitable for cultivating Arabica coffee of superior quality. Those regions with warm humid climate are well suited for growing Robusta coffee.

During 1990-91 area under coffee was 270821 ha with a total production of 169726 tonnes in India and it was increased to 454722 ha of area and 316000

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tonnes of production in 2017-18. Arabica coffee contributed 228910 ha of area, 95000 tonnes of production and Robusta coffee contributed 225812 ha of area, 221000 tonnes of production to total area and production of coffee in 2017-18 (GOI, 2018).

1.1.3 Production of Coffee in Kerala, Karnataka and Tamil Nadu

Coffee is mainly cultivating in the southern states *viz.*, Karnataka, Kerala and Tamil Nadu which accounted for 80.5 per cent of total area and 96.7 per cent of total production to all India. Arabica coffee contributed to 31.3 per cent of area, 26.8 per cent of production and Robusta coffee contributed 49.2 per cent of area, 69.9 per cent of production, to total area and production respectively.

Karnataka is the major coffee growing state in India. The major coffee growing districts of Karnataka are Chikmagalur, Kodagu and Hassan. Among these three districts Kodagu stands first in area, production and productivity. In Karnataka, during 2017-18 total coffee growing area was 244785 ha (Arabica 108795 ha and Robusta 135990 ha) with total production of 222300 tonnes (Arabica 69025 tonnes and Robusta 153275 tonnes). In Kerala, major coffee growing regions are Wayanad, Idukki, Travancore and Nelliampathies. Kerala accounted for total area of 85880 ha (Arabica 4231 ha and Robusta 81649 ha) and total production of 65735 tonnes (Arabica 2160 tonnes and Robusta 63575 tonnes) during 2017-18. The major coffee growing regions of Tamil Nadu are Pulneys, Shevroys, Anamalais and Nilgiris, all together contributes 35607 ha of total area (Arabica 29513 ha and Robusta 6094 ha) and 17400 tonnes of total production (Arabica 13400 tonnes and Robusta 4040 tonnes) during 2017-18 (GOI, 2018).

1.2 CARDAMOM

Cardamom (*Elettaria cardamom*) is one of the oldest known spices in the world. It is popularly known as "Queen of spices" because of its very pleasant aroma and taste (Agritech, 2019). It is the third most expensive spices after the saffron and vanilla. Botanically cardamom is a perennial tropical herb belonging to the *Zingibaraceae* family and grows around 6-10 feet height from thick rootstalk. Evergreen forests of Western Ghats of South India are considered as the centre of origin as well as natural habitat of cardamom (Radhakrishnan, 2003).

Cardamom is mainly grown in the tropical regions of the world. Major cardamom producing country in the world is Guatemala followed by India, Srilanka, Iran, Tanzania etc. India ranks second in the cardamom production. However, major production of cardamom in the world is from Guatemala. From last two decades, cardamom consumption had increased throughout the world. The major cardamom consuming countries includes the Saudi Arabia, United Arab Emirates, India, Pakistan, USA, European countries and Japan. Middle Eastern countries (Saudi Arabia and the United Arab Emirates) and South-East Asian countries such as India, Pakistan etc., accounted for more than 60 per cent of the world's total consumption. The largest importer of cardamom in the world is Saudi Arabia, followed by Kuwait, UAE, USA, Japan etc.

1.2.1 Cardamom in India

Cardamom (*Elettaria cardamom*) is mainly cultivating in hilly tracts of the Western Ghats of India. The areas in and around the Western Ghats are best suited for cardamom cultivation so, commercial cultivation of cardamom is concentrated in this region. Cardamom is mainly cultivating in areas which receiving annual rainfall of 1,500–4,000mm and temperature of 10°–35°C. The optimum elevation preferred by the cardamom plant is 600-1,500m above the mean sea level.

In 1990-91 cardamom growing area was 81554 ha; production was 4750 tonnes with productivity of 70 kg ha^{-1} in India. During 2017-18 area became 69330 ha with a production of 20650 tonnes and productivity of 391 kg ha^{-1} (GOI, 2018).

1.2.2 Cardamom in Kerala, Karnataka and Tamil Nadu

Cardamom is mainly cultivating in the southern states *viz.*, Kerala, Karnataka and Tamil Nadu which accounted for 100 per cent of area and 100 per cent of production to India. These are the only three states growing small cardamom in India.

Kerala is the major cardamom growing state in India. The major cardamom growing districts of Kerala are Idukki, Wayanad and Palakkad. Among these, Idukki stands first in area, production and productivity. The area under cardamom in Kerala was 39080 ha with production of 18350 tonnes and productivity of 581 kg ha^{-1} during 2017-18. The major cardamom growing districts in Karnataka are Shimogga, Hassan and Chikamagalur. The total area under cardamom in Karnataka was 25135 ha; production was 1450 tonnes and productivity of 82 kg ha^{-1} during 2017-18. The major cardamom growing regions of Tamil Nadu are Nilgiris, Anamalais, Nelliampatty and the Kodaikanal hills. Tamil Nadu accounted for a total area of 5115 ha, production of 850 tonnes and productivity of 238 kg ha^{-1} during 2017-18 (GOI, 2018). The major cardamom varieties grown in South India are CCS-1, ICRI-1, ICRI-2, Mudigere-1, PV-1, and SKP-14, and the variety "Njallani" developed by a cardamom farmer in Kerala (Agritech, 2019).

In order to get a good idea of how the area, production and productivity of these crops have varied over the years, it is necessary to study the trends and patterns over the years. Also it is important to understand the trends in area, production and productivity of these crops across the states.

Price is an import component of these two crops as it is profoundly influencing the income of the farmers. It is well documented that domestic price of the plantation crops is directly influenced by the price of the commodity in the international market in the present scenario of globalization (Paul *et al*, 2015). It would be better if we analyze the market price variation of these crops in different markets across the state. In this context the present study is proposed.

1.3 SPECIFIC OBJECTIVES OF THE STUDY

Comparative analysis on area, production, productivity and price of plantation crops such as coffee and cardamom across the states Kerala, Karnataka and Tamil Nadu, to develop statistical models for price volatility and to determine the factors responsible for performance.

1.4 SCOPE OF THE STUDY

From this study, we will come to know changes in area, production and productivity of coffee and cardamom in Kerala, Karnataka and Tamil Nadu. It helps in forecasting the future area, production and productivity. Moreover, domestic price volatility provides an understanding about inconsistency present in the price and income of farmers. It also helps to provide guidelines to policy makers and planners in formulating national production and price policies.

1.5 LIMITATIONS OF THE STUDY

The study is based on the secondary data collected from various sources. It is restricted to the plantation crops such as coffee and cardamom in Kerala, Karnataka and Tamil Nadu. In case of coffee, some analysis is based on wholesale price. However, an attempt has been made to have an in depth analysis of the data by using suitable statistical tools and techniques to arrive at meaningful conclusions.

1.6 PLAN OF THE THESIS

The whole study has been presented in five chapters. The first chapter deals with the introduction and importance of coffee and cardamom, objectives of the study and scope of the study. The second chapter includes the studies made in the past which are related to the objectives of the present study. The third chapter deals with collection of materials and statistical methods used for the analysis. In fourth chapter, results and discussions of the study are presented. The last chapter depicts the summary and conclusions drawn from the present study.

Review of Literature

2. REVIEW OF LITERATURE

A review of past research provides information to the researchers about the previous works done in their area and there by enable the researcher in identifying the conceptual and methodological issues relevant to the present study. This helps the researcher to collect relevant data, provides proper direction to carry out the research work and assists us to attain meaningful results. This chapter provides brief review of literature related to the present study. Keeping in view of the objectives of the study, the available literature has been reviewed and presented under the following headings.

2.1 Growth rates and trend analysis

2.2 Cointegration between market prices

2.3 Price volatility

2.4 Influencing factors on production

2.1. GROWTH RATES AND TREND ANALYSIS

Hasija *et al*. (2004) studied the growth and trends in area, production and productivity of wheat in Haryana during the period 1966-67 to 1998-99. The whole period of analysis was divided into three sub periods such as 1966-67 to 1976-77, 1977-78 to 1988-89 and 1988-89 to 1998-99. Haryana state had been divided into two Agro-climatic zones i.e. eastern zone and western zone. The Compound Annual Growth Rates (CAGR) and trends of area, production and productivity were worked out for all the three periods and for both the zones. Different models were fitted separately for area, production and yield of wheat for both the zones. Out of these, cubic model turned out to be best for area, production and productivity in both the zones except in one case i.e. in eastern zone in case of area; power function is considered to be best fit. Based on the compound annual growth rate as well as trend analysis showed that the area, production and productivity of wheat crop had increased significantly during 1966-67 to1998-99.

Lathika and Kumar (2005) analysed the growth trends in area, production and productivity of coconut in India for the five decades. The study is based on the secondary data of area (in hectares) under cultivation, production (in million nuts) and productivity (nuts per hectare) for a period of 52-years from 1950-51 to 2001-02. Three trend equations namely, semi-log ($lnY_t = a + b.t + u_t$), log quadratic ($lnY_t = a + b.t + c.t^2 + u_t$) and log-quadratic (modified) were worked out on the data of coconut. Trend equations were fitted to the 52-year time series data on area, production and productivity of coconut for all the coconut producing states and India as a whole. In case of area the exponential model was considered as the best fit for all the regions. For production also, the growth rate based on the exponential model was found to be best for all the regions. For productivity, the log-quadratic model (modified) which was found to be the best fit among the three models tried. The study concluded that coconut production in the country was largely determined by the four southern and coastal States of India, namely Kerala, Karnataka, Tamil Nadu and Andhra Pradesh and positive growth rate in area and production of coconut in India as well as at the state level.

Rajarathinam *et al.* (2010) carried out an investigation to study area, production and productivity trends and growth rate of tobacco crop in Anand region of Gujarat. Based on the parametric and nonparametric regression models trends and growth rates of tobacco on area, production and productivity studied for the period from 1949-50 to 2007-08. The parametric models included different linear, non-linear and time-series models. Statistically most suited models were selected based on adjusted R^2, co-efficient of determination (R^2) and significant regression coefficient. After adjusting the data for stationarity, appropriate time-series models were fitted and statistically best model was selected based on goodness of fit criteria viz., Akaike information criterion (AIC), Bayesian information criterion (BIC) etc. They concluded that none of the parametric model was found suitable to fit the trends in area, production and productivity of tobacco crop. Finally the nonparametric regression model was selected as best fitted model for area, production and productivity trend of tobacco crop based on lower root mean square and mean absolute errors. They made final statement that tobacco production had increased due to combined effect of increase in area and productivity.

Gairhe *et al.* (2011) conducted a study to know the growth in the quantity of export, value of export and to assess the direction of export of Indian coffee in the international market based on secondary data for the period from 1990 to 2008. The results of the study disclosed that the quantity of coffee exported from India and value of export were increased by 3.62 per cent and 7.52 per cent per annum respectively. The quantity of export was increased at medium rate; however, the growth in export value of coffee had increased more due to increase in price of coffee over the years in international market. The direction of trade showed that, Italy, Russia and Germany were more stable coffee importers from India. The results thus indicated that there was a wide scope to increase the export of coffee to international markets.

Prasad (2012) estimated as 1.93 per cent, 5.05 per cent and 2.98 per cent as compound annual growth rates for area, production and productivity of maize respectively in Telangana region of Andhra Pradesh during the study period from 1969 to 2009. The growth rate in production (5.05%) was higher than the growth rate in area (1.93%) and productivity (2.98%). Different growth models were fitted and best model was selected based on significant Adjusted R^2 for future projection.

The growth status in the area, production and productivity of different crops in Karnataka was estimated by Acharya *et al.* (2012) by using the compound growth function for a period of 26 years from 1982-83 to 2007-08. The estimated growth rates showed a significant positive growth in area under pulses, vegetables, fruits, spices and nuts while cereals showed significant negative growth. In cereals particularly, the area under jowar, ragi, bajra and minor millets were experienced a substantial annual decrement whereas the area under rice had showed a mild annual increment. The growth rate in area under oilseeds and commercial crops was found to be negative and insignificant. Similarly the production of cereals, pulses, vegetables and fruits revealed a significant positive growth whereas production of oilseeds and commercial crops showed insignificant positive growth. The productivity of different crops noted significant growth in the case of cereals, pulses and fruits. Similarly productivity of oilseeds showed moderately positive growth and productivity of commercial crops showed insignificant positive growth and for vegetables productivity the growth was insignificant and negative.

Karunakaran (2013) made an attempt to measure the impact of Liberalization, Privatization and Globalization (LPG) reforms on cashew nut cultivation in Kerala. The results showed the negative growth rate in production for cashewnut because of decline in area under cultivation as well as yield of cashew.

Karunakaran (2013) examined the growth trends of area, production and productivity of arecanut crop in Kerala. The study was based on the secondary data from 1960-61 to 2010-11. For measuring the growth trends of area, production and productivity of arecanut crop the entire period of analysis was divided into five sub-periods and an exponential model $Y=ab^t$ was estimated. The results of the analysis concluded that trend in area, production and productivity was increased significantly.

A study conducted by Greeshma (2014) to examine the trends and growth rates in area, production and productivity of sugarcane crop in Andhra Pradesh showed that increasing trend in area, production and productivity during the study period. Linear growth rate and compound growth rate showed increase in area, production and productivity every year in all regions of Andhra Pradesh except in Telangana region where area showed negative growth rate.

Koujalagi *et al.* (2014) made an attempt to estimate the growth trends in area, production, productivity and export of pomegranate in Karnataka as a whole state as well as in major pomegranate growing districts namely Koppal and

Bagalkot for the period from 1987-88 to 2009-10. The results of the study revealed that production had significant growth rate of 2.60 per cent per annum at one per cent level of significance and area with 2.29 per cent at 5 per cent level of significance for Karnataka. In Koppal district there was significant increase in growth in area (24.00 %) and production (25.35 %) because of implementation of various government schemes. As far as the export was concerned 27.86 per cent growth was observed. The study concluded that the increase in production of pomegranate was due to the increase in area, rather than productivity.

Selvi *et al.* (2015) estimated the growth trends for area, production and productivity of maize in India. The necessary secondary data were collected from 1970-71 to 2013-14 and trend equations were fitted to examine the pattern of growth dimensions. Findings exposed that the percentage of growth was higher in production (223.14 %) trailed by productivity (91.41 %) and area (60.63 %). Along with that linear growth rate was found to be more in terms of production and area than productivity. The study exposed that the increase in production of maize over the years mainly because of parallel expansion in area and productivity was not much contributed for enhancement of production.

Akhter *et al.*, (2016) conducted a study to analyze growth and trend in area, production and yield of major crops grown in Bangladesh and determined the growth pattern on total cultivable area, gross production and yield rate of major crops of Bangladesh such as rice, wheat, pulse, jute, rape and mustard, sugarcane & tea. They find out the trend and estimated the growth rate in area, production and yield of the above mentioned crops by using semi-log trend function on time series data of 40 years from 1969-74 to 2004-2009. The compound growth rate as well as trend analysis indicated that the production of rice during the study period was increased due to the corresponding increase in per hectare yield of rice. The result showed that area, production and yield of wheat were increased over the time because of more area was brought under wheat production except the year 2004-2009. It was noted that area, production and yield of pulse, rape and mustard were increased over the time whereas, the area, production and yield of jute was decreased. Also the results of the analysis revealed that the trend co-efficient of area, production and yield of sugarcane and tea was positive.

Netam and Sahu (2017) reported that in Chhattisgarh growth pattern in area of rice showed a downward trend at state, regional and district level by fitting on exponential function. Production of rice showed an upward trend at state and regional level and a downward trend in district level where as in the yield, the growth pattern was an upward at state, regional and district level during the study period.

Dastagiri (2017) studied the trends and growth rates in exports and price of Indian coffee from 1990–1991 to 2012–2013. The results of the study showed that, growth rate in export and price of Indian coffee was 4.9 per cent and 7.7 per cent respectively.

Sharma and Kispotta (2017) made an attempt to analyze the trends in area, production and productivity of banana crop in India and in Kaushambi district of Uttar Pradesh. The results of the study revealed that for as many as three years the growth rate of India's banana cultivation area had been negative, for three years it had been less than 5 per cent and for one year, the growth had been registered over 18 per cent. The increase in area under banana in the district of Kaushambi was 9.51 per cent from 2005-06 to 10-11 but the production has decreased by 26.38 per cent while productivity was increased by 1.3 per cent.

Niranjan *et al.* (2017) estimated the compound growth rates in area, production and productivity of cotton from the time series data for the period from 1950-51 to 2015-16 in India. The results of the study indicated that tremendous increase in the area under cultivation, production and productivity. Among all the three variability, production had a better improvement with an annual growth rate of 4 per cent followed by productivity (3%) and area (1%). Along with that, a vast variation had been observed in production with a CV of 53.82 per cent.

Kumar *et al.* (2017) conducted a study to analyze growth and instability in area (ha), production (tones) and productivity (kg ha^{-1}) of Cassava in Kerala during 1991 to 2016. The trends estimated using semi log function in the area, production, and productivity of cassava revealed that there was a significant decline in an area with a compound annual growth rate of 1.37 percent, the non-significant decline in production by -0.02 percent and a significant increase in productivity by 1.3 percent due to introduction of short duration varieties. Instability was found to be 4.04 percent in productivity which was highest.

Rajan and Palanivel (2018) studied the growth trends of area, production and productivity of cotton crop in India. The study was based on the secondary data for the period from 1951 to 2013. They estimated the growth trends of cotton on area, production, and productivity by using different models *viz.*, linear, quadratic, cubic, exponential, compound, logarithmic, inverse, power, S-curve, and growth model. All the fitted models were significant but cubic model was considered to the best fit model because it had highest R^2 as well as adjusted R^2 for cotton area (0.77), production (0.91) and productivity (0.91). By using best fitted cubic model they forecasted the future area, production and productivity of cotton crop up to 2020. The forecasted cotton statistics showed increasing trend on area, production and productivity.

A study conducted by Gayathri (2018) revealed that the trend in groundnut area showed decreasing trend, whereas production and yield showed an increasing trend in India. The compound growth rate in groundnut area showed the negative trend, production and yield showed a positive trend with an increase of 1 per cent and 3.26 per cent respectively. The results of the analysis revealed that the yield was contributed more by the production than by area. The major groundnut producing states in India except Madhya Pradesh and Rajasthan showed the negative trend for the area, production, and yield. While considering the production of groundnut, the states like Gujarat, Rajasthan Madhya Pradesh, and Uttar Pradesh have shown positive trend. Regarding the yield of groundnut in

Gujarat, Tamil Nadu and Maharastra showed positive trend during the reference period 2000-01 to 2015-16.

A study conducted by Kumari *et al.* (2018) accompanied with time series data from 1990-1991 to 2015-2016, on dynamics of area, production and productivity of jute in India. Whole period of analysis was divided into three sub periods as period 1 (1990-00), period 2 (2000-10), period 3 (2010-16) based on the decade. First period showed positive growth rate of 1.5 per cent for area whereas overall period, second period and third period showed negative growth of area 0.2 per cent, 0.9 per cent and 1.6 per cent respectively. Production showed positive growth rate of 2.3 per cent, 1.4 per cent and 1.3 per cent for first, second and overall period respectively while third period showed negligible growth rate for production. Also variability for area, production and productivity was calculated where; variation in yield was noticed as significant.

Agashe *et al.* (2018) carried out the study to know trends in area, production and productivity of groundnut in different districts of Chhattisgarh. The results indicated that trend analysis of the area of groundnut was positively and significantly increased in all districts due to increased irrigation facilities and the use of low cost input technology. Also the production and productivity pattern of groundnut was positively and significantly increased due to increased area, the use of fertilizers and pesticides by the farmer and introduction of high yielding varieties (HYP).

To study the growth status of major pulses in Karnataka and India, Avinash and Patil (2018) were calculated growth rate in area, production, productivity of selected pulse crops for a period of 36 years from 1980 – 2016. In India, as a whole the results showed positive growth in area, production and productivity in all the period. Also in pertain to Karnataka, total pulses scenario revealed that the growth in area, production and productivity were positive.

2.2 COINTEGRATION BETWEEN MARKET PRICES

Indira (1988) determined the degree of price relationship for coffee between the three major wholesale centers namely Bangalore, Vijayawada and Coimbatore. The results of the study exposed that prices have shown positive relationship with both Vijayawada and Coimbatore prices. Vijayawada and Coimbatore prices also showed positive relationship with each other. However, there was comparatively lesser influence of Bangalore wholesale prices on Coimbatore wholesale prices than on Vijayawada wholesale prices of coffee.

The co-integration approach was used by Sinha and Nair (1994) to examine the black pepper price variations in the world market. Due to open trade status of black pepper, observed that its prices had moved synchronously, that was an indication of integration of the world-black pepper market. The prices of black pepper did not deviate much due to oligopolistic nature of the world market for black pepper. Also found that supply variables were responsive to the conditions of international market.

Baharumshah and Habibullah (1994) used the co-integration technique to examine the long run relationship among pepper prices in six different Malaysian markets. The co-integration technique was applied to weekly pepper prices for the period from 1986 to 1991. The empirical results of the study showed that regional markets of pepper in Malaysia were highly co-integrated and also observed that pepper prices tended to move homogeneously across spatial markets which was an indication of competitive pricing behaviour.

Nasrudeen and Subramanian (1995) analyzed the integration of oil and oilseeds prices in Bombay market. The analysis revealed the nature of price integration between oils and oilseeds. In case of castor oil the assumption of complete oil price integration could not be fully accepted and current belief of impact of groundnut oil prices on all edible oil prices was also established. The results of integration established the hypothesis that changes in oilseed price is related to changes in its oil and oilcake prices. The Bombay markets of oilseeds showed the characteristics of perfect market condition by its nature of quick adjustments to price changes.

Kumar and Sunil (2004) employed the Johansen co-integration technique to analyze the efficiency of spot and future markets for five commodities in six Indian commodity exchanges. They confirmed inefficiency of future market based on inability of future market to fully incorporate information. The results of the analysis concluded that the Indian agricultural commodities future markets are not yet mature and efficient.

Basu (2006) made an attempt to examine the potato markets integration by using co-integration test in Hooghly district of West Bengal. The analysis had been made at two levels, by considering wholesale markets and retail markets. Johansen co-integration test was applied to weekly prices of three important potato markets, suggested that the markets were integrated. The results of the analysis confirmed that price signals and information were transmitted smoothly across the markets. These results had importance in policy implications, success of price policy and market liberalization programs undertaken in India.

Alam and Begum (2007) studied the functioning of some selected commodity markets in terms of price relationship to each other for the period of 1986-2005 in Bangladesh. Spatial price integration of markets had been evaluated for Aman (HYV), Boro (HYV), wheat, mustard and lentil crops in selected districts. Results of the study revealed that Aman HYV markets were well integrated but the Boro HYV markets were not well integrated.

A study conducted by Lokare (2007) found that, almost all the commodities in Indian commodity market showed an indication of co-integration between spot and future prices enlightening the correct direction of attaining the improved operational efficiency, though at a slower rate.

Saran and Gangwar (2008) tested the co-integration between the major wholesale egg markets in India. Engle-Granger co-integration test procedure had been applied to egg price series for major wholesale egg markets in the country, *viz*. Chennai, Bangalore, Nammakal (Tamil Nadu), Calcutta, Delhi and Hyderabad for the period 1982 to 2000. Before applying the co-integration test stationarity of the individual wholesale egg price series were tested using the Augmented Dickey-Fuller (ADF) test. The results of ADF test showed that all the price series were non-stationary but first differences of the series were almost stationary. Thus, the test of co-integration was applied as all the egg price series were integrated of the same order, i.e. I(1) and did not have unit root. The cointegration between markets was studied using the Engle-Granger test and the results indicated that the six major wholesale egg markets in the country were co-integrated. The markets were co-integrated due to performance of market intelligence functions by the National Egg Coordination Committee which helps in transmitting price signals across the country.

Goyari and Jena (2011) investigated the daily future and spot prices of commodities like crude oil, gold and guar seed for the period from June 2005 to Jan 2008. Co-integration test was used in this study and the outcomes revealed that spot and future prices of these three commodities were co-integrated or moving in a synchronized manner.

Jain and Arora (2014) studied the Co-integration between future and spot prices of selected agricultural commodity black pepper traded on the National Commodity Derivatives Exchange of India Ltd. for the period from June 2008 to May 2013. The results of the study revealed that that there was a co-integration between future and spot prices of black pepper which, indicates that both future and spot markets have performed dependently.

Nirmala *et al.* (2015) studied cointegration between the futures price and spot price of cardamom, to determine whether cardamom futures market serves as a price discovery mechanism for spot market prices and vice versa. The study involved the use of econometric tools like Augmented Dickey Fuller (ADF) test, Granger Causality test and Co-integration technique for the analysis of data from Jan 2012 to Dec 2013. The results of the ADF test revealed that time series data was stationary at first difference and not at level. The co-integration test showed that cardamom futures and spot prices were cointegrated and there exists 2 cointegration equations which confirmed that long-term relationship between the futures and spot price series.

Meera *et al.* (2015) conducted a study for cointegration analysis of wholesale price of wheat in selected market of Sriganganagar district in Rajasthan. Markets selected for market integration study were Sriganganagar, Sadulsahar, Gharsana, Anupgarh, Vijaynagar, Suratgarh, Gajsinghpur, Karanpur and Raisinghnagar. The stationarity of individual market price series tested, results of the Augmented Dickey-Fuller (ADF) unit root test showed that the existing data were non-stationary. After taking first difference, all the series became stationary which is confirmed from the ADF test results i.e. all the calculated values (-9.296 to -14.181) for all the markets price series were less than the critical value (- 4.038). Johansen's co-integration test for wheat markets indicated the presence of at least eight co-integrating equation at 5per cent level of significance hence, markets were having long run equilibrium relationship. The pairwise Granger's causality test for selected markets showed significant at 1 percent level which was indicative of mutual influence exerted by the markets on each other.

Mahalle *et al.* (2015) had examined the wheat markets integration in Maharashtra. They selected seven markets, out of which, four markets had been found spatially integrated. Among the selected wheat markets some market pairs had depicted bidirectional causality, while others had shown unidirectional causality. Almost all the selected wheat markets had shown long-run equilibrium relationship and existence of co-integration among them.

Sharma and Burark (2015) conducted a study to test market integration of wholesale gram markets in Rajasthan for the period from 2003 to 2012 based on monthly wholesale prices of seven gram markets in Rajasthan. The results of the Augmented Dickey-Fuller (ADF) test showed that the existing gram price series were non-stationary but their first differences were stationary. Hence the price series of gram were integrated of the order 1 i.e. I (1). The results of Johansen's co-integration test revealed that markets were integrated and having long run equilibrium relationship. The outcomes of Granger Causality Test showed that most of the markets had bidirectional as well as unidirectional influences on gram prices and these markets affected by prices of each other.

Naveena *et al.* (2016) made an attempt to analyse the impact of world coffee price on Indian coffee price by considering monthly wholesale price of Arabica coffee and Robusta coffee seeds and monthly indicator price of world market prices of Arabica coffee and Robusta coffee from 1999 to 2013. Before applying the co-integration test stationarity of the individual wholesale coffee price series were tested using the Augmented Dickey-Fuller (ADF) test. The results of ADF test showed that all the price series were non-stationary but first differences of the series were became stationary. Johansen's cointegration test was carried out to find the long run relationship between Indiana coffee market and world coffee market. The results of study revealed that there was a long run association between Indian Arabica coffee price and world Arabica coffee price as well as Indian Robusta coffee price and world Robusta coffee price.

Awasthi *et al.* (2016) studied the market integration and price volatility across soybean markets in central India (Madhya Pradesh) based on the monthly time series data on prices and arrivals of Soybean from five major soybean markets of Madhya Pradesh namely Ashtha, Dewas, Indore, Mandsaur and Shajapur for a from 2001-02 to 2013-14. Stationarity of the series were tested using Augmented Dickey-Fuller test (ADF) which showed that the prices of soybean were non-stationary and became stationary after taking the first difference. Co-integration of the selected markets were tested using Johansen Co-integration test and most of the selected markets showed bidirectional influence on soybean prices of each other. The results indicated that the market prices had a long-run equilibrium/co-movement among the Indore, Dewas, Astha, Mandsaur and Shajapur markets during the study period. The existence of co-integration was necessary for long-term market efficiency.

Awasthi *et al.* (2017) analysed the integration among the major garlic markets in the Madhya Pradesh. Monthly average wholesale prices and arrivals of garlic were collected from major markets *viz.* Indore, Mandsaur, Ratlam, Neemuch and Ujjain in Madhya Pradesh for the period 2001-02 to 2013-14. Negative relationship was observed between the garlic price and garlic arrival in the markets of Madhya Pradesh. The prices of garlic were non-stationary and observed higher in the months from November to January (lowest arrivals months) across the selected markets. The price series showed the consequences of unit root i.e. non-stationarity and were became stationary at first difference. Johansen's co-integration test showed long run equilibrium relationship and co-integration between selected markets Indore, Mandsaur, Neemuch, Ratlam and Ujjain. Most of the selected markets of garlic showed unidirectional influence on garlic prices of each other, whereas Mandsaur and Indore markets showed the bidirectional influence on prices.

A study conducted by Vigila *et al.* (2017) aimed to investigate the potato market integration in India from Jan 2005 to Sept 2016. Specifically they concentrated on how the Tamil Nadu potato market performs with respect to the behavior of other potato markets across India. Madhya Pradesh, Gujarat and Uttar Pradesh were the major potato markets, which have a major share in the total supply of potato to Tamil Nadu, were selected for analysis of market integration. Engle- Granger co-integration technique was used. The analysis of month wise potato price data revealed that long run equilibrium existed among the potato markets in Tamil Nadu, Uttar Pradesh, Madhya Pradesh and Gujarat but the speed of adjustment of equilibrium level is very slow in the long run. Change in the potato price of Gujarat market was the main key determinant of shocks in the Tamil Nadu potato market.

Indira *et al.* (2017) conducted a study to analyze market Co-integration of Barley markets in Hanumangarh District (Hanumangarh, Rawatsar, Bhadra, Sangaria, Pilibanga, Nohar and Goluwala) of Rajasthan. Secondary data consists of monthly wholesale prices of seven selected markets of Rajasthan from 2005 to 2014 were used for co-integration analysis. To test the stationarity of the series Augmented Dickey-Fuller (ADF) unit root test was used. The results of the Augmented Dickey-Fuller (ADF) unit root test showed that the existing data were non-stationary but after taking first difference, all the series became stationary. Hence, the price series of barley were integrated of the order 1.

Johansen's co-integration test for barley showed the presence of at least five co-integration equations at 5 per cent level of significance. Therefore, selected markets were having long run equilibrium relationship and co-integration between them. The results of Granger causality test for barley indicated the presence of bidirectional influence on barley prices of Bhadara to Pilibanga, Pilibanga to Goluwala, Sangaria to Rawasar, Pilibanga to Nohar, Rawatsar to Nohar, Nohar to Goluwala, Rawatsar to Pilibanga, Pilibanga to Hanumangarh, and Hanumangarh to Rawatsar. Other markets showed a unidirectional influence on market prices. All these results indicated the presence of long run integration among all the markets of Hanumangarh district of Rajasthan.

Emam *et al.* (2018) made an attempt in the study to understand the nature of the sorghum market integration in Sudan. The study was mainly based on monthly wholesale price of sorghum in Khartoum, Elobied, Gdarif and Damazin markets, which was collected for the period from January 2012 to December 2016. Unit Root test, Johnson cointegration test and Error Correction model were used to study stationary series, the long run relationship and short run relationship between these selected markets, respectively. The result showed that after first difference, absolute ADF statistics are greater than the critical t-values at 1% level of significance so, the null hypothesis of a unit root was rejected. Therefore all the series are 1(1) and stationary. Johansen co-integration test showed long run relationship between all pairs of markets, except between Khartoum and Elobied markets. This integration may be due to the fact that these markets are connected by good communication and transportation.

2.3. PRICE VOLATILITY

Satheesh *et al.* (1988) used the recent developments in time series modeling to examine the retail prices of beef, chicken and pork. Mainly, generalized autoregressive conditional heteroscedasticity (GARCH) models were fit to these data to determine the conditional variances of the underlying stochastic processes which were not constant. The estimated results also rejected the assumption of constant conditional variance.

Yang *et al.* (2001) examined the effect of the radical agricultural liberalization policy, on price volatility of agricultural commodity using Generalized Autoregressive Conditional Heteroscedasticity (GARCH) models. The outcomes of the study showed that the agricultural liberalization policy had caused an increase in the price volatility for three major commodities such as corn, soybeans and wheat, also little increase in the volatility of oats but decrease in the volatility cotton.

Jordaan *et al.* (2007) determined conditional volatility in the daily spot prices of yellow maize, white maize, wheat, soybeans and sunflower seed traded on the South African Futures Exchange. They used GARCH approach because the volatility in the prices of crops had been found to vary over time. Analysis showed that the white maize price was found to be the more volatile, trailed by yellow maize, sunflower seed, soybeans, and wheat respectively.

Gemech and Struthers (2007) conducted a study to know the influence of market reform programmes in Ethiopia on the coffee prices volatility by using the Generalised Autoregressive Conditional Heteroscedastic (GARCH) model. The study period include from 1982 to the end of 2001. The outcomes of the study showed that Ethiopia had experienced a significant increase in volatility of coffee price after the implementation of the market-oriented reform programmes.

Hojatallah and Ramanarayanan (2010) showed volatility in Indian stock market (BSE500 stock index) by using ARCH and GARCH models. They concluded that GARCH (1, 1) model describes volatility of the Indian stock markets in a better way. Observed that the sum of ARCH and GARCH parameter was closer to unity (0.97) which indicates that a shock at time *t* continues for many future periods, which means they have long memory.

Worako *et al.* (2011) made an attempt to quantify the volatility in the price of coffee in Ethiopia by using Autoregressive Conditional Heteroscedasticity/Generalized Autoregressive Conditional Heteroscedasticity (ARCH)/(GARCH) approach by considering producer, wholesale and export prices from October 1981 to September 2006. In order to compare the price risk as faced by the participants in the coffee chain volatility was estimated separately for producer, wholesale and export prices, also compared to the volatility levels in Brazilian coffee prices, since Brazil is a major coffee producing country in the world. The GARCH (1,1) model ($\sigma^2{}_t = \alpha_0 + \alpha_1 u_{t-1}^2 + \beta_1 \sigma_{t-1}^2$) was fitted for each price series separately and the results of the study revealed that Coffee prices within Ethiopia were found to be more volatile than in Brazil. Producer prices were found to be the most volatile, followed by wholesale prices and export prices respectively.

A study by Ibrahim and Bruno (2011) modeled and forecasted volatility in the global food commodity prices of wheat, rice, sugar, beef, coffee and groundnut by using standard GARCH(1, 1) model. The analyses revealed the evidence of leptokurtosis in the volatility of food commodity prices. They also exposed that for most of the commodities the volatility of the future commodity prices exhibits short memory behaviour.

Poudel (2012) conducted a study to investigate the effects of production of large cardamom in Nepal and India on large cardamom price volatility in Nepal as well as effect of small cardamom production in India on large cardamom price volatility in Nepal. GARCH model was applied to analyze the price volatility by using monthly wholesale price data from January 2001 to October 2009. The results of the study revealed that production volume of large cardamom in Nepal and India played a positive role in reducing price volatility of large cardamom whereas, production of small cardamom in India played no effect on price volatility of large cardamom in Nepal.

Sendhil *et al.* (2013) estimated the degree of price volatility in the spot market by using GARCH model and determined GARCH (2, 1) model was best for wheat and maize. Based on the results of analysis reported that, none of the spot price were volatile indicating the helpfulness of future trading and also showed that volatility in the present day prices depends on volatility in the previous day prices.

Sundaramoorthy *et al.* (2014) estimated the volatility persisting in the groundnut markets of Hyderabad and Rajkot using GARCH model. GARCH (1, 1) was selected as the suitable model for the price series of both the markets and results of the study revealed that the groundnut price in Hyderabad market exhibited a high and persisting volatility as compared to the groundnut price in Rajkot market. The sum of α and β coefficients of GARCH model for Hyderabad and Rajkot market were 0.41 and 0.20 respectively.

Paul *et al.* (2015) estimated price volatility of Bengal gram in Delhi market, Lentil grain in Indore market and Rapeseed and Mustard oil in Sri Ganganagar market using daily spot price data from 1 Jan 2007 to 31 July 2013. The price level of these three commodities had increased over the period and showed wide fluctuation in the commodities prices. Empirical results of GARCH Model exposed that the value of first-order autoregressive term ARCH and value of first-order moving average term GARCH were significant in the price series of commodities pertaining to study period. The value of GARCH term was relatively large in comparison to ARCH term exposed reasonably long persistence of

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volatility. The determined volatility was also pretty high in selected commodities during most of the years.

2.4. INFLUENCING FACTORS ON PRODUCTION

Vijay Kumar *et al.* (1991) collected fortnightly weather data and annual yields of arecanut (*Areca*) and cocoa (planted in a mixed cropping trial in 1970) for 1977-88. Seven weather variables were correlated with yield for both the current year and a one-year lag period. Arecanut yield was significantly correlated with rainfall and maximum RH of the previous year, and with minimum RH, maximum temperature, pan evaporation and rainfall of the current year. Cocoa yield was significantly correlated with the number of rainy days in the previous year, and sunshine hours, maximum and minimum temperatures of the current year.

Joshi (1999) studied the dependence of area and production of major crops (pearl millet, ground nut and rain fed cotton) on rainfall in dry farming area in Gujarat, India. The study examined whether any relationship can be established to suggest optimum period of planting these crops and also forecast expected area coverage and production. Data were collected from 1961-62 to 1991-92. The study resulted that the time of onset of monsoon becomes the deciding factor for area covering and later on in production of many major crops. Adequate rainfall in the early period of monsoon increases area of cash crops like ground nut in Saurastra region, whereas with inadequate rainfall in this period, farmers opt for cultivation of coarse cereals like pearl millet. The adequate rainfall during the early growth period of cotton had a positive influence on its production.

Guruswamy *et al.* (2008) were studied the effects of weather parameters on coconut productivity in Thanjavur district, Tamil Nadu, India, during 1996 to 2005 and stated that southwest monsoon and winter rainfall had a negative correlation with coconut productivity, whereas summer and rainfall had a positive correlation with coconut productivity. The percentage of barren nut production in coconut had a positive correlation with summer rainfall and negative correlation with winter, southwest and northeast monsoons. The maximum temperature, minimum temperature, relative humidity, pan evaporation and rainfall had a positive correlation with coconut productivity.

Sunil *et al.* (2011) Conducted research at Regional Agricultural Research Station, Ambalavayal, Wayanad, Kerala on the relationship between the yield of Areca nut and weather parameters *viz.* temperature, relative humidity and rainfall. The results of the study revealed that during flowering stage *i.e.*, January to March, an increase in minimum temperature, relative humidity and rainfall had significant positive influence on nut yield. In contrast, rainfall during the nut development stage (from June to July) adversely affected the crop yield. Areca nut prefers high relative humidity particularly during the morning period throughout its growth period.

Bunn *et al.* (2014) studied the impact of climate change on global production of Arabica and Robusta coffee by using machine learning algorithms. The results of the study suggested that higher temperatures may reduce yields of Arabica coffee, while Robusta coffee could suffer from increasing variability of intra-seasonal temperatures. Also, made conclusion that climate change will reduce the global area suitable for coffee by about 50 per cent and impact of climate change were highest at low latitudes and low altitudes. The world's major coffee production regions in Brazil and Vietnam may experience substantial reductions in area.

Birthal *et al.* (2014) studied how weather parameters were influencing Indian agriculture by taking weather parameters such as rainfall and temperature as independent variables and production as dependent variable from 1969 to 2005 for 200 districts. The results of the study revealed that rise in temperature would reduce productivity whereas rainfall, unless it becomes excess, counterbalances harmful effects of temperature. They reported that irrigation is a vital adaptation strategy to diminish temperature effect.

Iqbal and Siddique (2015) studied the influence of weather parameters on agricultural productivity in Bangladesh from 1975 to 2008. Rice productivity was taken as dependent variable and climatic variables such as temperature, rainfall and humidity as independent variables. The results of the study showed that, increase in the average minimum temperature during dry season resulted increase in rice output.

Tokunaga *et al.* (2015) analysed the impact of climate change on agriculture in Japan by considering production as dependent variable and precipitation, temperature and solar radiation as independent variables from 1995 to 2016. The results of the study showed that, 1°C increase in temperature caused reduction in rice production by 5.8 per cent in short term and by 3.9 per cent in long term. Similarly, in case of vegetables and potatoes, 1 °C increase in temperature caused reduction in production by 5 per cent in short term and 8.6 per cent in long term.

Kumar *et al.* (2016) calculated the impact of weather parameters on land productivity of 15 Indian crops from 1989 to 2009. In the model, productivity of the crop was taken as dependent variable and climatic parameters such as minimum temperature, maximum temperature and rainfall were taken as independent variables. The study was revealed that, land productivity might go down by 3.29 per cent because of 1 per cent increase in annual temperature.

Jayakumar *et al.* (2017) conducted a study to know Impact of climate variability on coffee yield in Kerala during the period 1980 -2014. In this study variability in yield of Arabica and Robusta coffee due to variability in weather parameters such as rainfall , maximum temperature , minimum temperature and mean relative humidity was estimated by considering yield as dependent variable and weather parameters as independent variables using linear multiple regressions. The yield data revealed that the yield of Robusta coffee was higher than that of Arabica coffee in most of the years due to favorable climate conditions for Robusta coffee in Kerala. There was increasing trend of yield of

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Robusta coffee in Kerala and decreasing trend of Arabica coffee. In case of Robusta coffee blossom showers had significant influence in increasing the yield of coffee rather than total annual rainfall. It was observed that whenever the annual rainfall was high, Arabica and Robusta coffee yield was poor.

Materials and Methods

3. MATERIALS AND METHODS

The present study is conducted with an overall objective of comparative analysis on area, production, productivity and price of plantation crops like coffee and cardamom across states Kerala, Karnataka and Tamil Nadu, to analyse the price volatility and co-integration of markets. This chapter provides brief description about selection of crops, data collection and various statistical tools and models utilized in the present study. The details are presented under the following headings.

3.1 Description of study area

3.2 Database and source of data

3.3 Methods for Statistical Analysis

3.1 DESCRIPTION OF STUDY AREA

3.1.1 Coffee

One among the largest producer of coffee in the world, India stands on seventh position for coffee production. Out of the total world production of coffee, India's production accounted for 3.30 per cent to world production in 2017-18. Coffee is the second most consumed beverage in the world, after Tea. Coffee has been a major export earning commodity of several coffee growing countries in the world. India accounted 5.40 per cent of share to total world export during 2017-18.

India cultivates both the commercially important species of coffee, *viz.*, *Coffea arabica* (Arabica coffee) and *Coffea canaphora* (Robusta coffee). In India coffee has grown in an area of 454722 ha among which 228910 ha is under Arabica and 225812 ha is under Robusta. India's total production of coffee was 316000 tonnes in which 95000 tonnes contributed by Arabica and 221000 tonnes by Robusta during the year 2017-18 (GOI, 2018).

In India coffee is an important plantation crop, which is mainly cultivated in the southern states *viz.*, Karnataka, Kerala and Tamil Nadu which accounted for 96.7 per cent of the total production in India. The major coffee growing areas are Chikamagalur, Coorg and Hassan districts in Karnataka, Wayanad, Idukki, and Nelliampathy in Kerala and Pulneys, Shevroys, Anamalai's and Nilgiris in Tamil Nadu. Karnataka accounted for 53.8 per cent of the planted area, contributing about 70.3 per cent production to all India. Kerala state accounted for 18.9 per cent of planted area under coffee and 20.8 per cent production to all India. However, the per cent share of area (7.8%) and production (5.5%) was less in Tamil Nadu as compared to Kerala and Karnataka to all India during the year 2017-18 (GOI, 2018). The area and production of three South Indian states Kerala, Karnataka and Tamil Nadu is presented in the Table 1.

Table 1. Area and production of coffee in South Indian states during 2017-18.

	State	Arabica	%	Robusta	%	Total	%
	Kerala	4231	0.9	81649	18	85880	18.9
	Karnataka	108795	23.9	135990	29.9	244785	53.8
Area(ha)	Tamil Nadu	29513	6.5	6094	1.3	35607	7.8
	Total	142539	31.3	223733	49.2	366272	80.5
	All India	228910	50.3	225812	49.7	454722	100
	Kerala	2160	0.7	63575	20.1	65735	20.8
	Karnataka	69025	21.8	153275	48.5	222300	70.3
Production (Tonnes)	Tamil Nadu	13400	4.2	4040	1.3	17400	5.5
	Total	84585	26.8	220890	69.9	305475	96.7
	All India	95000	30.1	221000	69.9	316000	100

% - per cent share to all India

3.1.2 Cardamom

India is the second largest producer of cardamom in the world. The forests of Western Ghats of South India are considered as the Centre of origin as well as natural habitat of cardamom. Approximately, 69330 ha of area scattered throughout the hill forest zone of the Western Ghats under cardamom with production of 20650 tons in 2017-18 (GOI, 2018). About 50 per cent of the area lies in the cardamom hills in Travancore - Cochin, 23 per cent in Shimoga, Hassan and Chikamagalur Districts, 13 per cent in Kodagu District in Karnataka and 13 per cent in the southern foothills of the Nilgiris, the Anamalai, the Nelliampatty and the Kodaikanal hills of Tamil Nadu.

The South Indian states Kerala, Karnataka and Tamil Nadu together contributes 100 per cent area and production of small cardamom in India. Kerala accounted for 56.37 per cent of the area, contributing about 88.86 per cent total production of cardamom in India. While Karnataka and Tamil Nadu accounted for 36.25 per cent and 7.38 per cent of cardamom area with a production of 7.03 per cent and 4.11 per cent respectively during the year 2017-18 (GOI, 2018). The area and production of cardamom in three South Indian states *viz.* Kerala, Karnataka and Tamil Nadu is presented in the Table 2.

Table 2. Area and production of cardamom in South Indian states during 2017-18

State	Area(ha)	Percentage (%)	Production(Tonnes)	Percentage (%)
Kerala	39080	56.37	18350	88.86
Karnataka	25135	36.25	1450	7.03
Tamil Nadu	5115	7.38	850	4.11
All India	69330	100	20650	100

% - per cent share to all India

3.2 DATABASE AND SOURCE OF DATA

The present study is based on secondary data. The secondary data pertaining to the area, production, productivity and price of coffee and cardamom across the states Kerala, Karnataka, and Tamil Nadu were collected from concerned commodity boards like coffee board and spices board, Government of India for a period of past twenty five years from 1993-94 to 2017-18 . Secondary data pertaining to weather parameters such as rainfall, temperature and relative humidity (RH) were collected for Wayanad district from Regional Agricultural Research Station (RARS), Ambalavayil, Kerala agricultural university (KAU) and for Idukki district from Cardamom Research Station (CRS), Pampadumpara, KAU.

3.2.1 Coffee

In case of coffee, data on area (ha), production (tonnes) and productivity (kg ha^{-1}) was collected for Arabica coffee and Robusta coffee separately from various publications of Coffee Board, GOI, Bengaluru. After harvesting, the produced coffee was processed and categorized into different grades such as Arabica Plantation A, Arabica Cherry AB, Robusta Parchment AB and Robusta Cherry AB. Therefore, for cointegration analysis monthly average wholesale price (Rs kg^{-1}) of Arabica Plantation A and Robusta Cherry AB grades of coffee was collected from Bengaluru and Chennai markets for a period from January 1995 to December 2017. However, to understand the fluctuations in domestic market price, monthly average auction price (Rs 50 kg^{-1}) of Arabica plantation A, Arabica Cherry AB and Robusta Parchment AB grades of coffee was collected from Bengaluru market for the period from January 1998 to December 2017.

3.2.2 Cardamom

Area (ha), production (Tonnes) and productivity (kg ha^{-1}) of cardamom in three South Indian states was collected from publications of Spices Board, GOI, Cochin for the period from 1990-91 to 2017-18. Auction system was followed in the marketing of cardamom. The growers bring their processed cardamom or cured cardamom to the nearby auction centers and register the lots (i.e. the bag of cardamom) for auction. The auctioneer report the number and quality of cardamom in each lot kept for auction. Samples from each lot are distributed among the dealers and bidders. The exporters or traders bid for each lot and a lot is sold to a particular exporter who bids the maximum price. The average of auction price (Rs 100 kg^{-1}) of various lots in different auction centers in Kerala and Karnataka were collected from Spices Board, GOI, for a period from August 1990 to July 2018 to analyze the cointegration between markets and volatility in domestic price of cardamom.

3.2.3 Main items of observations

Area (ha), production (tonnes) and productivity (kg ha^{-1}) of coffee and cardamom were collected for study period. Wholesale price of coffee (Rs kg^{-1}) in Bengaluru and Chennai market, auction price of coffee (Rs 50 kg^{-1}) in Bengaluru market, auction price cardamom (Rs 100 kg^{-1}) in Kerala and Karnataka markets and weather parameters such as rainfall(mm), temperature (°C) and relative humidity (%) for Wayanad and Idukki districts were also collected for study period.

3.3 METHODS FOR STATISTICAL ANALYSIS

In this section, a brief description of statistical methods employed is presented.

3.3.1 Methods for fitting the trend equations

Trend is the general tendency of a variable or series of data points to move in a certain direction over time. To find the best model for trends in area, production and productivity of coffee and cardamom different growth models were fitted. The models which describe the behavior of a variable overtime are known as growth models. The growth models taken under consideration are as follows.

3.3.1.1 Semi log model:

The mathematical form of the model is given by

$$\ln Y_t = b_0 + b_1 t + \varepsilon_t$$

where,

Y_t - dependent variable *viz.,* area, production and productivity at time t

t - time in years, independent variable

b_0 and b_1 are constants or parameters

ε_t - error terms

The parameters in above equation are estimated by using the least squares method of estimation.

3.3.1.2 Double logarithmic model:

This model shows very rapid growth, followed by slower growth. The mathematical equation of the model is given by

$$\ln Y_t = b_0 + b_1 \ln(t) + \varepsilon_t$$

where,

Y_t - dependent variable *viz.,* area, production and productivity at time t

t - time in years, independent variable

b_0 and b_1 are constants or parameters

ε_t - error terms

The parameters in above equation are estimated by using the least squares method of estimation.

3.3.1.3 Inverse model:

Generally inverse curve shows a decreasing growth. The equation for the inverse model is given as

$$\ln Y_t = b_0 + \frac{b_1}{t} + \varepsilon_t$$

where,

Y_t- dependent variable *viz.,* area, production and productivity at time t

t - time in years, independent variable

b_0 and b_1 are constants or parameters

ε_t - error terms

The parameters in above equation are estimated by using the least squares method of estimation.

3.3.1.4 Quadratic model:

This function is useful when there is a peak or a trough in the data of past periods. The mathematical equation of the model is given by

$$\ln Y_t = b_0 + b_1 t + b_2 t^2 + \varepsilon_t$$

where,

Y_t - dependent variable *viz.,* area, production and productivity at time t

t - time in years, independent variable

b_0, b_1, and b_2 are constants or parameters

ε_t - error terms

The parameters in above equation are estimated by using the least squares method of estimation.

3.3.1.5 Cubic model:

This function is useful when there is, two peaks or two troughs in the data of previous periods. Cubic fit or third degree curve is given by the equation:

$$\ln Y_t = b_0 + b_1 t + b_2 t^2 + b_3 t^3 + \varepsilon_t$$

where,

Y_t - dependent variable *viz.,* area, production and productivity at time t

t - time in years, independent variable

b_0, b_1, b_2 and b_3 are constants or parameters

ε_t - error terms

The parameters in above equation are estimated by using the least squares method of estimation.

3.3.1.6 Compound model:

This function is useful when it is known that there is or has been, increasing growth or decline in past periods. Compound model equation is given by

$$Y_t = b_0 b_1^t u_t$$

$$\ln(Y_t) = \ln(b_0) + t\ln(b_1) + \varepsilon_t$$

where,

Y_t - dependent variable *viz.,* area, production and productivity at time t

t - time in years, independent variable

b_0 and b_1 are constants or parameters

ε_t - error terms $(\varepsilon_t = \ln u_t)$

The parameters in above equation are estimated by using the least squares method of estimation.

3.3.1.7 Power model:

The mathematical equation of the power function is given by

$$Y_t = b_0 t^{b_1} u_t$$

$$\ln(Y_t) = \ln(b_0) + b_1 \ln(t) + \varepsilon_t$$

where,

Y_t - dependent variable *viz.,* area, production and productivity at time t

t - time in years, independent variable

b_0 and b_1 are constants or parameters

ε_t - error terms $(\varepsilon_t = \ln u_t)$

The parameters in above equation are estimated by using the least squares method of estimation.

The model is similar to exponential model, but produces a forecast curve that increases or decreases at different rate.

3.3.1.8 Exponential model:

If, when the values of *t* are arranged in an arithmetic series, the corresponding values of *Y* form a geometric series, the relation is of the exponential type.

The mathematical equation of the exponential function is given by

$$Y_t = b_0 e^{(b_1 t)} u_t$$

$$\text{or } \ln(Y_t) = \ln(b_0) + b_1 t + \varepsilon_t$$

where,

Y_t - dependent variable *viz.,* area, production and productivity at time *t*

t - time in years, independent variable

b_0 and b_1 are constants or parameters

ε_t - error terms $(\varepsilon_t = \ln u_t)$

The parameters in the above equation are estimated by method of least using the least squares.

3.3.1.9 Model selection criteria

To choose best model among the several competing models, different goodness of fit criteria such as adjusted R^2, normality of residuals and randomness of residuals have been used. The best model was selected, such that it has high adjusted R^2, which satisfies the assumptions of independent and normally distributed errors.

3.3.1.9.1 Coefficient of determination (R^2)

The coefficient of determination is a key part of regression analysis and one of the measures of goodness of fit of a regression model. It is interpreted as the proportion of the variance in the dependent variable explained by the independent variables. The value of R^2 lies between 0 and 1. The value is nearer to 1, the better is the fit. If R^2 is zero that means dependent variable cannot be predicted from the independent variables. If R^2 is one, it means that dependent variable can be predicted from the independent variables without any error. The R^2 lies between 0 and 1 indicate the extent to which the dependent variable is predictable.

How well the estimated model fits the data can be measured by the value of R^2. In general, R^2 measures the percentage of variation explained by the independent variables in the total variability, which is given by

$$R^2 = \frac{SSR}{TSS} = 1 - \frac{SSE}{TSS}$$

Where *SSR*= sum of squares due to regression ($\hat{\beta}X'Y$), *TSS*= total sum of squares ($Y'Y$) and SSE= error sum of squares ($TSS - SSR$).

By using F test, significance of R^2 have been tested

$$F = \frac{R^2}{(1-R^2)} \cdot \frac{n-k-1}{k}$$ which follows $F_{(k,\, n-k-1)}$ degrees of freedom.

where k = number of regressors variables in the model, n is the number of observations.

The main problem of R^2 is that, R^2 cannot fall when more variables are added to the model. Therefore, there is a chance of maximizing the R^2 by simply adding more variables to the model.

3.3.1.9.2 Adjusted R^2 $(\overline{R}^2)$

Henry Theil (1961) developed a measure based on R^2 known as adj. R^2 to avoid adding regressors to increase the R^2 value, which is denoted by $\overline{R}^2$.

$$\overline{R}^2 = 1 - \frac{SSR/(n-k-1)}{TSS/(n-1)} = 1-(1-R^2)\frac{n-1}{n-k-1}$$

where k = number of regressors variables in the model, n is the number of observations. The term adjusted means; it is adjusted for the degrees of freedom associated with the sum of squares. From above formula it is clear that $\overline{R}^2$ is always less than R^2. For comparative purpose, $\overline{R}^2$ is a better measure than R^2. The $\overline{R}^2$ increases only if the added new variable improves the model more than would be expected by chance.

3.3.1.10 Residual analysis

After fitting the different models, it is necessary to check the assumptions of residuals of the models. So two most important assumptions made in the models are

- Residuals are normally distributed
- Residuals are randomly distributed

3.3.1.10.1 Test for normality: Shapiro-Wilk test

There are many tests available to test the normality. Some of the popular tests for normality are Shapiro – Wilk test, Cramer Von Misses test, Kolmogorov-Smirnov test *etc.* The Shapiro-Wilk test is the common and better, if the sample size is less than 2000.

Shapiro-Wilk test statistic 'W' is given as

$$W = \frac{\left[\sum_{i=1}^{n} a_i X_{(i)}\right]^2}{\sum_{i=1}^{n} (X_i - \overline{X})^2}$$

where, $X_{(i)}$ = ordered sample values, $i=1, 2, \ldots, n$, $\overline{X}$ is the overall mean.

a_i = constants generated from mean, variance and covariance of the order statistics of a sample size n from a normal distribution.

In this test, H_0: Residuals are normal. If the p-value is greater than critical value, usually 0.05, H_0 is accepted and we conclude that residuals are normal. Shapiro-Wilk test statistic W, ranges in between 0 and 1 and highly skewed to the right.

3.3.1.10.2 Test for randomness: Runs test

Randomness of residuals can be tested by using non-parametric test called runs test. A run is defined as an uninterrupted sequence of identical symbols in which the individual scores or observations originally were obtained. Consider an example where series of binary events occurred in this order

+ + - - - + + - - - - + + - - +

If the number of runs is very few, a time trend or positive autocorrelation is present. If the number of runs is many, systematic short-period cyclical fluctuations seem to be influencing the scores. In the above example there are seven runs.

In a sequence of $N=N_1+N_2$ binary events, let N_1 be the number of elements of one kind and N_2 be the number of elements of another kind. If both N_1 and N_2 are less than 20, then the number of runs present in the sequence is defined as R, if lies between the confidence interval then do not reject the null hypothesis i.e. events are random.

For large samples if either N_1 or N_2 is larger than 20, a good approximation to the sampling distribution of 'R' is the normal distribution with,

Mean = $E(R) = \frac{2N_1N_2}{N} + 1$

Standard deviation= $\sigma_R = \sqrt{\frac{2N_1N_2(2N_1N_2 - N)}{N^2(N-1)}}$

Then H_0 may be tested by $Z = \frac{R - E(R)}{\sigma_R}$

The significance of any observed value of Z computed by using the equation may be compared with critical value of normal distribution with α level of significance.

3.3.2 Compound annual growth rate (CAGR)

To analyze the comparative change in area, production and productivity of coffee (Arabica coffee and Robusta coffee) and cardamom over the years in Kerala, Karnataka and Tamil Nadu compound annual growth rates were estimated. Compound annual growth rates of area, production and productivity of coffee (Arabica and Robusta) and cardamom were estimated by using exponential model and its mathematical equitation is given as

$$Y_t = b_0 e^{(b_1 t)} \varepsilon_t$$

$$\text{or } \ln(Y_t) = \ln(b_0) + b_1 t + \varepsilon_t$$

Y_t- dependent variable (area, production and productivity)

t - time in years, independent variable

b_0 and b_1 are constants or parameters

ε_t - error term

The constants in the above equation are estimated by the method of ordinary least squares.

The compound annual growth rate (CAGR %) was calculated by using the formula

$$\text{CAGR (\%)} = (Antilog\ b_1 - 1) \times 100$$

The significance of compound annual growth rates can be tested by using student's *t* test.

$$t = \frac{r}{SE(r)}$$ with (n-2) degrees of freedom (df).

where, r - growth rate

n - total number of years considered under study

SE(r) - standard error of growth rate

3.3.3 Cointegration technique

The cointegration approach is mainly used to analyze the co-movement of two time series data instead of using correlation coefficient. Generally the time series data are expected to suffer from non stationarity and heteroscedasticity. So, correlation coefficient is not an efficient tool in case of non-stationary time series data.

According to this approach, any two series are said to be co-integrated when series cannot drift from each other in the long run and there exists a mechanism which equilibrate to bring the two series together. In other words, there exists a long run equilibrium relationship between them. Applying this idea to price in any two given markets, cointegration between their price series denotes long run interdependence between these markets. Since, the major principle of market integration is the price dependency across markets. It follows that cointegration between price series of two given markets implies integration of those two markets.

The cointegration approach to market integration is naturally appealing and straightforward in application. The markets are said to integrate if prices of markets are determined interdependently. Between integrated markets generally assume that the price changes in one market will be fully transmitted to the other markets. The markets which are not integrated may transfer inaccurate price information that might mislead marketing decisions and contribute to inefficient product movement.

To inspect the price relationship between any two markets, let us consider the following basic relationship that is commonly used to test for the presence of market integration.

$$Y_{it} = \alpha_0 + \alpha_1 Y_{jt} + \varepsilon_t$$

where Y_{it} and Y_{jt} are price of a specific commodity in two markets *i* and *j* at time *t*. ε_t is the error term assumed to be independently and identically distributed (iid) with constant variance. If Y_{it} and Y_{jt} are stationary variables then the test of market integration is straightforward. Hence, it is important to check whether the variables are stationary or not.

3.3.3.1 Test for stationarity

If the series is stationary, this means that the series has constant mean and variance which does not change over the period. Roughly speaking, a time series is stationary if its behavior does not change over time.

Generally the concept of stationarity can be summarized by the following conditions. A time series $\{Y_t\}$ is said to be stationary if:

$E(Y_t) = E(Y_{t-s}) = \mu$,

$E(Y_t - \mu)^2 = E(Y_{t-s} - \mu)^2 = \sigma_y^2$

$E(Y_t - \mu)(Y_{t-s}-\mu) = E(Y_{t-j}-\mu)(Y_{t-j-s}-\mu) = \gamma(s),\ s \geq 1$

where μ, σ_y^2 and γ(s) are all time invariant.

Consider the equation,

$$Y_t = Y + \varepsilon_t$$

where, Y_t is the observed value of the series at time *t*, *Y* is the mean value of the series and ε_t is a random disturbance term. The series Y_t is said to be stationary as expressed as I (0). But often the series tend to display an increase or decrease, which violates the above condition. In such case successive differencing would reduced the series to stationary, thus,

$$Y_t - Y_{t-1} = \varepsilon_t \text{ or } Y_t = Y_{t-1} + \varepsilon_t$$

A series which becomes stationary after differencing once is said to be integrated of order 1 and it is expressed as I (1). In general, a series which must be differenced "d" time to become stationary is expressed as I (d). A major difference between I(0) and I (d) , *d*>0 series is that the I(0) series has a finite mean and variance, while in I (d) series this magnitudes do not exist.

3.3.3.2 Augmented Dickey –Fuller Test

To determine the order of integration or to test stationarity the following test referred to as the Augmented Dickey – Fuller (ADF) test is employed. The ADF test is comparable with the simple DF test, but is augmented by adding lagged values of the first difference of the dependent variable as additional repressors which is required to account for possible occurrence of autocorrelation. The ADF test is based on the relation

$$\Delta Y_t = \alpha + \beta Y_{t-1} + \sum_{i=1}^{p} \delta_i \Delta Y_{t-i} + \varepsilon_t$$

where, Y_t denotes the variable being tested, $\varepsilon_t \sim iid\ N(0, \sigma^2)$, $\beta = 1 - \rho$ and

$\Delta Y_t = Y_t - Y_{t-1}$, $\Delta Y_{t-1} = (Y_{t-1} - Y_{t-2})$, $\Delta Y_{t-2} = (Y_{t-2} - Y_{t-3})$, etc. α, β and δ_i are parameters to be estimated. The null and alternative hypotheses tested is

H_0: $\beta = 0$ or Y_t is not I(0), against H_1: $\beta < 0$ or Y_t is I(0)

The test statistic is the conventional t-ratio

$$t = \frac{\hat{\beta}}{SE(\hat{\beta})}$$

where $\hat{\beta}$ is the ordinary least square (OLS) estimate of β and $SE(\hat{\beta})$ is the standard error. But, Dickey and Fuller (1979) showed that under the null hypothesis of a unit root, this statistic does not follow the conventional Student's *t* distribution and it follows the τ (*tau*) statistic. They also computed the critical values of the *tau statistic* on the basis of Monte Carlo simulations for various sample sizes. Later, MacKinnon (1991, 1996) had developed more extensive critical values than those tabulated by Dickey and Fuller. In addition, MacKinnon estimates response surfaces for the simulation results, permitting the calculation of Dickey-Fuller critical values and *p*-values for arbitrary sample sizes.

In general, if the estimate of β is negative and significantly different from zero, then reject the null hypothesis, H_0 which indicates that series is stationary.

3.3.3.3 Engle- Granger test for cointegration

Engle-Granger co-integration technique was used to understand market integration or co-movement of prices in Bengaluru and Chennai markets for two grades of coffee and integration between cardamom auction prices in Kerala and Karnataka markets.

In Engle-Granger co-integration technique, before testing the cointegration, it is necessary to test whether the series are stationary or non-stationary by using conventional unit root tests. If the series are non-stationary, check whether, they are integrated of same order or not. If they are integrated of the same order, say I (d), there exists a co-integrating relationship between them. It can be expressed as below,

$$Y_t = \alpha_0 + \alpha_1 X_t + \varepsilon_t$$

where Y_t and X_t are two spatially separated time series, ε_t is the error term, α_1 is the co-integrating coefficient and the equation is referred to be as the co-integrating regression model. The error terms ε_t of co-integrating regression model are tested for stationarity or for order of integration. Y_t and X_t are cointegrated only if the residual term ε_t is integrated of order zero, I(0) or stationary.

Co-integration between the prices of markets was evaluated by regressing the price of one market with that of the price in another market and the residuals were tested for the order of integration.

3.3.4 Volatility analysis

Volatility poses a big challenge in modeling financial time series like agricultural prices, stock prices, exchange rates, inflation, etc. Variation in the economic variables over a period of time is referred as volatility. The price volatility is the degree of variation of a price series over time. One of the most important points is that the volatility changes over time and that is not directly visible in daily data since there is only one observation for each trading day.

One of the traditional and classical assumptions of conventional time series and econometric models is constant variance. In case of volatility, data in which the variances of the error terms are equal is said to follow homoscedasticity. The homoscedasticity assumption has the inference that uncertainty or volatility remains constant over time which is not true. Opposite to homoscedasticity, data in which the expected value of the error terms is not equal, in which the error terms may reasonably be expected to be larger for some points or ranges of the data than for others, is said to suffer from heteroscedasticity. Such a time series with varying variance are modeled by autoregressive conditional heteroscedasticity (ARCH) and generalized autoregressive conditional heteroscedasticity (GARCH) models. These ARCH and GARCH models allowed the conditional variance to change over time as a function of past errors leaving the unconditional variance constant; it was the first model that provides a systematic form for volatility modeling.

In this study we were focused on variations in the auction price of different grades of coffee in Bengaluru market and auction price of cardamom in Kerala and Karnataka markets over time.

3.3.4.1 ARCH-LM Test

The presence of ARCH effect (whether or not volatility varies over time) has to be tested through the squared residuals of the series (Tsay, 2005). The most commonly used method to test for ARCH effect is Lagrange-Multiplier test. In this test first estimate the mean equation using OLS,

$$y_t = \beta_0 + \beta_1 y_{t-1} + \dots\dots + \beta_k y_{t-k} + \varepsilon_t$$

Let ε_t be the residual series to test the conditional heteroscedasticity. Then $\{\varepsilon_t^2\}$ is the squared residual series which is used to check for conditional heteroscedasticity, which is also known as the autoregressive conditional heteroscedastic (ARCH) effects. Lagrange's Multiplier (LM) test was used for testing conditional heteroscedasticity, for testing H_0: $\gamma_1 = 0$ and $\gamma_2 = 0$ and $\gamma_3 = 0$ and ... and $\gamma_q = 0$ in the linear regression where squared residuals were regressed them on q own lags to test for ARCH of order q

$$\varepsilon_t^2 = \gamma_0 + \gamma_1 \varepsilon_{t-1}^2 + \gamma_2 \varepsilon_{t-2}^2 + \dots + \gamma_q \varepsilon_{t-q}^2 + e_t$$

Obtained R^2 from this regression and the test statistic is defined as $n.R^2$ (the number of observation multiplied by the coefficient of multiple correlation) from the last regression, and is distributed as a χ^2 with q degrees of freedom. If the value of the test statistic is greater than the critical value of χ^2 distribution with α level of significance, then reject the null hypothesis, which indicates presence of ARCH effect.

3.3.4.2 ARCH Model

The Autoregressive Conditional Heteroscedasticity (ARCH) type models are defined in terms of the distribution of errors of a linear regression model by taking dependent variable as commodity price which is considered as an autoregressive process. That means

$$y_t = \beta_0 + \beta_1 y_{t-1} + ... + \beta_k y_{t-k} + u_t \quad \text{where } u_t = \sigma_t \varepsilon_t, \ \epsilon_t \sim iid\, \text{N}(0, 1),$$

Engle (1982) developed a model for σ_t^2 based on past squared errors (u_t) of above equation known as conditional variance. The conditional variance depends on the previous q lagged innovations is denoted as ARCH (q) and is represented as

$$\sigma_t^2 = \alpha_0 + \alpha_1 u_{t-1}^2 + ... + \alpha_q u_{t-q}^2 \qquad \text{where } \alpha_0 > 0, \alpha_i \geq 0 \text{ for } i > 0 \text{ and } \sum \alpha_i \leq 1$$

In the equation it can be seen that large values of the innovation of price has a bigger impact on the conditional variance because they are squared, which means that a large shock have tendency to follow the other large shock and this behaviour is named as the clusters of the volatility.

3.3.4.3 GARCH Model

In the ARCH model there are several restrictions that have to be fulfilled so that the model can sufficiently estimate the volatility, which can be a problem. And in ARCH model, the conditional variance of the error term depends on the previous error term of different lags. But the problem of this model is that, at higher lag the model comprises of several parameters which makes the estimation difficult and lengthy. Therefore, Bollerslev (1986) recommend a transformation of the ARCH model, to a generalized ARCH model (GARCH), where conditional variance of error term depends not only on the previous squared errors but also on its conditional variances in the previous time periods. GARCH (p, q) model has two equations named as mean equation and variance equation

$$y_t = \beta_0 + \beta_1 y_{t-1} + ... + \beta_k y_{t-k} + u_t \qquad u_t = \sigma_t \varepsilon_t$$

$$\sigma^2{}_t = \alpha_0 + \sum_{i=1}^{q} \alpha_i u_{t-i}^2 + \sum_{j=1}^{p} \beta_j \sigma_{t-j}^2$$

where $\epsilon_t \sim iid\ N(0,1)$, the parameters α_i are the ARCH parameters and β_j are the GARCH parameters where $i = 1, 2, ...p$, $j = 1, 2, ...q$ and $\alpha_0 > 0$, $\alpha_i \geq 0$, $\beta_j \geq 0$ and $\sum_{i=1}^{\max(p,q)} (\alpha_i + \beta_j) < 1$. A simple form GARCH (p, q) is GARCH (1, 1), given as

$$\sigma^2{}_t = \alpha_0 + \alpha_1 u_{t-1}^2 + \beta_1 \sigma_{t-1}^2$$

The restriction on the ARCH and GARCH parameters (α_i, β_j) suggests that the volatility (u_t) is finite and that the conditional standard deviation increases (σ_t).If the sum of $(\alpha_i + \beta_j)$ i.e. ARCH and GARCH coefficients close to 1,it indicates that volatility shocks are quite persistent in the prices series and greater is the tendency of price volatility to persist for longer time in the variable under consideration.

3.3.4.4 Akaike Information Criterion (AIC)

After fitting the model it is necessary to verify the adequacy of the model. To choose the best model, different techniques are available. AIC is a one of the common diagnostic checking methods. It is estimated as

$$AIC = e^{\frac{2k}{n}} \frac{SSR}{n}$$

Where k is the number of parameters in the model, SSR is regression sum of squares and n is the number of observations. For mathematical convenience above equation written as

$$\ln AIC = \left(\frac{2k}{n}\right) + \ln\left(\frac{SSR}{n}\right)$$

where ln AIC is the natural log of AIC. Many statistical packages define AIC only in terms of its log transform so there is no need to put *ln* before AIC. In selection of model, the model which has low Akaike Information Criterion (AIC) is selected.

3.3.5 Multiple linear regressions

Multiple linear regressions analysis is a statistical tool that allows investigating how independent variables are related to a dependent variable. In this study, to find factors responsible for production of coffee and cardamom multiple linear regressions were carried out. In Kerala, major share of coffee production is from Wayanad district. So, production of coffee from Wayanad district is taken as dependent variable and quarterly weather parameters such as temperature, rainfall and relative humidity of the same district are taken as independent variables along with price. In case of cardamom, production of cardamom from Idukki district is considered as dependent variable and quarterly weather parameters such as temperature, rainfall and relative humidity of the same district are considered as independent variables. In this section we consider production of coffee as a function of weather parameters and one year lagged price.

$$\ln Y_t = \beta_0 + \sum_{i=1}^{4} \beta_i \ln(TQ_{it}) + \sum_{i=1}^{4} \gamma_i \ln(RQ_{it}) + \sum_{i=1}^{4} \delta_i \ln(RHQ_{it}) + \lambda \ln P_{t-1} + \varepsilon_t$$

where,

Y_t = coffee production in Wayanad during t^{th} period.

TQ_{1t} = Temperature during February to April in t^{th} period.

TQ_{2t} = Temperature during May to July in t^{th} period

TQ_{3t} = Temperature during August to October in t^{th} period.

TQ_{4t} = Temperature during November to January in tth period.
RQ_{1t} = Rainfall during February to April in tth period.
RQ_{2t} = Rainfall during May to July in tth period.
RQ_{3t} = Rainfall during August to October in tth period.
RQ_{4t} = Rainfall during November to January in tth period.
RHQ_{1t} = Relative Humidity during February to April in tth period.
RHQ_{2t} = Relative Humidity during May to July in tth period.
RHQ_{3t} = Relative Humidity during August to October in tth period.
RHQ_{4t} = Relative Humidity during November to January in tth period.
P_{t-1} = Price of coffee during t-1th period.

For cardamom, the model is specified as

$$\ln Y_t = \beta_0 + \sum_{i=1}^{4} \beta_i \ln(TQ_{it}) + \sum_{i=1}^{4} \gamma_i \ln(RQ_{it}) + \sum_{i=1}^{4} \delta_i \ln(RHQ_{it}) + \varepsilon_t$$

Y_t = cardamom production in Idukki during tth period.
TQ_{1t} = Temperature during January to March in tth period.
TQ_{2t} = Temperature during April to June in tth period.
TQ_{3t} = Temperature during July to September in tth period.
TQ_{4t} = Temperature during October to December in tth period.
RQ_{1t} = Rainfall during January to March in tth period.
RQ_{2t} = Rainfall during April to June in tth period.
RQ_{3t} = Rainfall during July to September in tth period.
RQ_{4t} = Rainfall during October to December in tth period.
RHQ_{1t} = Relative Humidity during January to March in tth period.
RHQ_{2t} = Relative Humidity during April to June in tth period.
RHQ_{3t} = Relative Humidity during July to September in tth period.
RHQ_{4t} = Relative Humidity during October to December in tth period.
The coefficients in the equations were estimated using OLS method.

3.3.5.1 Detection of multicollinearity

The existence of linear relationship between some or all explanatory variables of regression model causes serious problem in estimation, prediction and inference is referred as multicollinearity. To detect multicollinearity among independent variables variance inflation factor (VIF) of each variable is worked out using following formula.

Consider the regression model

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \ldots + \beta_k x_k + \ldots + \beta_{p-1} x_{p-1} + \varepsilon$$

The variance inflation factor for the kth variable is calculated as

$$VIF_k = \frac{1}{1 - R_k^2}$$

Where, R_k^2 is the R^2- value obtained by regressing the k^{th} variable on the remaining variables. If the VIF value is more than 10 for any independent variable, that particular independent variable is considered to have serious multicollinearity with the other independent variables.

3.3.5.2 Detection of autocorrelation

Autocorrelation is the correlation between successive terms series of observations ordered according to time or space. It relates to correlation between successive values of the same variable. The presence of autocorrelation is the violation of assumption of ordinary regression. So Durbin – Watson test was used to check the autocorrelation.

It was estimated using the formula:

$$d = 2(1 - \rho)$$

$$\rho = \frac{\sum e_t e_{t-1}}{\sum e_t^2}$$

where,

d = Durbin – Watson value.

ρ = Correlation coefficient of error terms.

If the value of d = 2 then, the model is said to have no autocorrelation.

3.3.6 Statistical packages used in the study

In the present study, SPSS 16.0 package was used for fitting the trend equations and estimating the compound annual growth rates. The open source software 'Gretl' was used for cointegration technique and volatility analysis. STATA 12.0 was used for multiple linear regressions analysis.

Results and Discussion

4. RESULTS AND DISCUSSION

In accordance with the specific objectives of the present research study, the required data collected are subjected to analysis using statistical techniques outlined in the previous chapter. This chapter deals with presentation and interpretation of the results obtained along with relevant discussions. For convenience, the results of analysis are presented under the five sub headings as follows:

4.1 Trend models

4.2 Comparative analysis on area, production and productivity of coffee and cardamom among South Indian states

4.3 Cointegration between market prices

4.4 Price volatility

4.5 Influencing factors on production

4.1 TREND MODELS

The models which describe the behavior of a variable overtime are known as growth models. In the present study, different linear and nonlinear growth models such as semi-log, double logarithmic, inverse, quadratic, cubic, compound, power and exponential models were fitted to understand the trends in area, production and productivity of coffee and cardamom in Kerala, Karnataka and Tamil Nadu. The best model was selected based on adjusted R^2, criteria of randomness and normality. The growth models were fitted by using the IBM.SPSS 16.0 package.

4.1.1 Coffee

Eight different growth models were fitted to study the trends in area, production and productivity of coffee in South Indian states Kerala, Karnataka and Tamil Nadu. The results of fitted models are presented with discussions.

4.1.1.1 Trends in area, production and productivity of coffee in Kerala

Different trend models fitted for area under coffee in Kerala are presented in Table 3 along with adjusted R^2, Shapiro-wilk test statistic to test normality of error terms and run test for independence of error terms. The adjusted R^2 value of fitted models ranged from 56.4 per cent for inverse model to 92.1 per cent for cubic model. In addition, all the estimated coefficients of the model were significant; errors were independent and normal for cubic model. Double logarithmic, quadratic and power models also had high adjusted R^2 (88%), significant estimated coefficients, errors distribution as normal but they were not random. Therefore, cubic model was considered as the best fitted model for trends in area under coffee in Kerala. The model was given as

$$\ln Y_t = 11.305 + 0.007t - 0.0001t^2 + 9.138*10^{-6}\, t^3 \quad (\text{Adj. } R^2 = 0.921)$$

Shapiro-wilk test: 0.951 (p-value = 0.268)   Run test: -2.00 (p-value = 0.051)

The graph of the actual and fitted trends for area under coffee in Kerala using cubic model is shown in Figure 1.

Eight different trend models fitted for production of coffee in Kerala are presented in Table 4 along with adjusted R^2, Shapiro-wilk test statistic to test for normality of error terms and run test for independence of error terms. The adjusted R^2 value of fitted models ranged from 44.6 per cent for inverse model to 63.6 per cent for cubic model. Cubic and double logarithmic models also had high adjusted R^2 (63.6% and 62.9% respectively), significant estimated coefficients, errors followed normal distribution but errors were not random in both the models. Next to these two models, quadratic model depicted high Adj. R^2 of 58.8 per cent, significant estimated coefficients, Shapiro-wilk test as well as run test was non-significant for the residuals indicating that residuals distributed normally and random. Therefore quadratic model was considered as the best fitted model for trends in production of coffee in Kerala. The model was given as

$$\ln Y_t = 10.635 + 0.042t - 0.0001t^2 \qquad (\text{Adj. } R^2 = 0.588)$$

Shapiro-wilk test: 0.970 (p-value = 0.655) Run test: -1.629 (p-value = 0.103)

The graph of the actual and fitted trends for production of coffee in Kerala using quadratic model is shown in Figure 2.

The different trend models fitted for productivity of coffee in Kerala are presented in Table 5 along with adjusted R^2, Shapiro-wilk test statistic to test normality of error terms and run test for independence of error terms. The adjusted R^2 value of fitted models ranged from 43.2 per cent for inverse model to 61.4 per cent for double logarithmic, cubic and power model. Among the fitted models, cubic, double logarithmic and power models had high adjusted R^2 (61.4%), significant estimated coefficients, errors followed normal distribution but errors were not random in all the three models. Next to these three models, quadratic model had high Adjusted R^2 of 57.3 per cent, significant estimated coefficients and errors were independent and normal. Therefore quadratic model was considered as the best fitted model for trends in productivity of coffee in Kerala. The model was given as

$$\ln Y_t = 6.226+0.039t-0.0001t^2 \qquad (\text{Adj. } R^2\text{=0.573})$$

Shapiro-wilk test: 0.970 (p-value = 0.642) Run test: -1.629 (p-value = 0.103)

The graph of the actual and fitted trends for productivity of coffee in Kerala using quadratic model is shown in Figure 3.

Table 3. Fitted linear and non-linear models for area of coffee in Kerala.

	Models	Regression coefficients				Goodness of fit			F-ratio
		b_0	b_1	b_2	b_3	Adj. R^2	Shapiro-wilk test	Run test	
1	Semi-log $\ln Y = b_0 + b_1(t) + \varepsilon$	11.322** [0.002]	0.002** [0.0001]			0.818	0.950 (0.246)	-4.051 (0.000)	108.977**
2	Double logarithmic $\ln(Y) = b_0 + b_1 \ln(t) + \varepsilon$	11.309** [0.003]	0.015** [0.001]			0.880	0.979 (0.867)	-3.266 (0.001)	176.498**
3	Inverse $\ln(Y) = b_0 + \frac{b_1}{t} + \varepsilon$	11.351** [0.002]	-0.048** [0.009]			0.564	0.948 (0.228)	-3.266 (0.001)	31.991**
4	Quadratic $\ln(Y) = b_0 + b_1(t) + b_2 t^2 + \varepsilon$	11.314** [0.003]	0.003** [0.001]	-6.85E-5** [0.0001]		0.878	0.933 (0.100)	-3.244 (0.001)	87.062**
5	Cubic $\ln(Y) = b_0 + b_1(t) + b_2 t^2 + b_3 t^3 + \varepsilon$	11.305** [0.003]	0.007** [0.001]	0.0001** [0.001]	9.13E-6** [0.001]	0.921	0.951 (0.268)	-2.000 (0.051)	94.850**
6	Compound $Y = b_0 b_1{}' \varepsilon$	11.322** [0.002]	1.002** [0.000]			0.818	0.950 (0.245)	-4.051 (0.000)	108.977**
7	Power $Y = b_0 t^{b_1} \varepsilon$	11.309** [0.003]	0.015** [0.001]			0.880	0.979 (0.866)	-3.266 (0.001)	176.498**
8	Exponential $Y = b_0 e^{(b_1 t)}$	11.322** [0.002]	0.002** [0.000]			0.818	0.950 (0.245)	-4.051 (0.000)	108.977**

Value in ( ) - p value

Value in [ ] – standard error

*- significant at 5% level of significance

**- significant at 1% level of significance

Table 4. Fitted linear and non-linear models for production of coffee in Kerala.

	Models	Regression coefficients				Goodness of fit			F-ratio
		b_0	b_1	b_2	b_3	Adj. R^2	Shapiro-wilk test	Run test	
1	Semi-log $\ln Y = b_0 + b_1(t) + \varepsilon$	10.75** [0.047]	0.016** [0.003]			0.520	0.944 (0.181)	-1.585 (0.113)	26.976**
2	Double logarithmic $\ln(Y) = b_0 + b_1 \ln(t) + \varepsilon$	10.597** [0.060]	0.158** [0.024]			0.6291	0.975 (0.770)	-2.000 (0.046)	41.760**
3	Inverse $\ln(Y) = b_0 + \frac{b_1}{t} + \varepsilon$	11.048** [0.031]	-0.545** [0.121]			0.446	0.949 (0.242)	-3.266 (0.001)	20.329**
4	Quadratic $\ln(Y) = b_0 + b_1(t) + b_2 t^2 + \varepsilon$	10.635** [0.069]	0.042** [0.012]	0.0001* [0.0001]		0.588	0.970 (0.655)	-1.629 (0.103)	18.115**
5	Cubic $\ln(Y) = b_0 + b_1(t) + b_2 t^2 + b_3 t^3 + \varepsilon$	10.502** [0.093]	0.098** [0.030]	-0.006* [0.003]	0.0001 [0.001]	0.636	0.970 (0.646)	-2.857 (0.004)	14.995**
6	Compound $Y = b_0 b_1{}^t \varepsilon$	10.751** [0.046]	1.017** [0.003]			0.520	0.944 (0.182)	-1.585 (0.113)	26.976**
7	Power $Y = b_0 t^{b_1} \varepsilon$	10.600** [0.058]	0.158** [0.024]			0.639	0.974 (0.746)	-2.000 (0.046)	41.760**
8	Exponential $Y = b_0 e^{(b_1 t)}$	10.751** [0.046]	0.017** [0.003]			0.520	0.944 (0.182)	-1.585 (0.113)	26.976**

Value in ( ) - p value Value in [ ] – standard error

*- significant at 5% level of significance **- significant at 1% level of significance

Table 5. Fitted linear and non-linear models for productivity of coffee in Kerala.

	Models	Regression coefficients				Goodness of fit			F-ratio
		b_0	b_1	b_2	b_3	Adj. R^2	Shapiro-wilk test	Run test	
1	Semi-log $\ln Y = b_0 + b_1(t) + \varepsilon$	6.333** [0.045]	0.015** [0.003]			0.511	0.947 (0.218)	-1.585 (0.113)	26.085**
2	Double logarithmic $\ln(Y) = b_0 + b_1 \ln(t) + \varepsilon$	6.190** [0.058]	0.148** [0.024]			0.614	0.979 (0.863)	-2.857 (0.004)	39.182**
3	Inverse $\ln(Y) = b_0 + \frac{b_1}{t} + \varepsilon$	6.611** [0.029]	-0.509** [0.116]			0.432	0.951 (0.265)	-3.266 (0.001)	19.227**
4	Quadratic $\ln(Y) = b_0 + b_1(t) + b_2 t^2 + \varepsilon$	6.226** [0.066]	0.039** [0.012]	0.0001* [0.0001]		0.573	0.970 (0.642)	-1.629 (0.103)	17.105**
5	Cubic $\ln(Y) = b_0 + b_1(t) + b_2 t^2 + b_3 t^3 + \varepsilon$	6.107** [0.091]	0.089** [0.030]	-0.006* [0.003]	0.0001* [0.0001]	0.614	0.974 (0.756)	-1.857 (0.004)	13.725**
6	Compound $Y = b_0 b_1^t \varepsilon$	6.333** [0.044]	1.016** [0.03]			0.511	0.948 (0.222)	-1.585 (0.113)	26.091**
7	Power $Y = b_0 t^{b_1} \varepsilon$	6.193** [0.055]	0.148** [0.024]			0.614	0.978 (0.845)	-2.038 (0.042)	39.130**
8	Exponential $Y = b_0 e^{(b_1 t)}$	6.333** [0.044]	0.016** [0.003]			0.511	0.948 (0.222)	-1.585 (0.113)	26.091**

Value in ( ) - p value
Value in [ ] – standard error
*- significant at 5% level of significance
**- significant at 1% level of significance

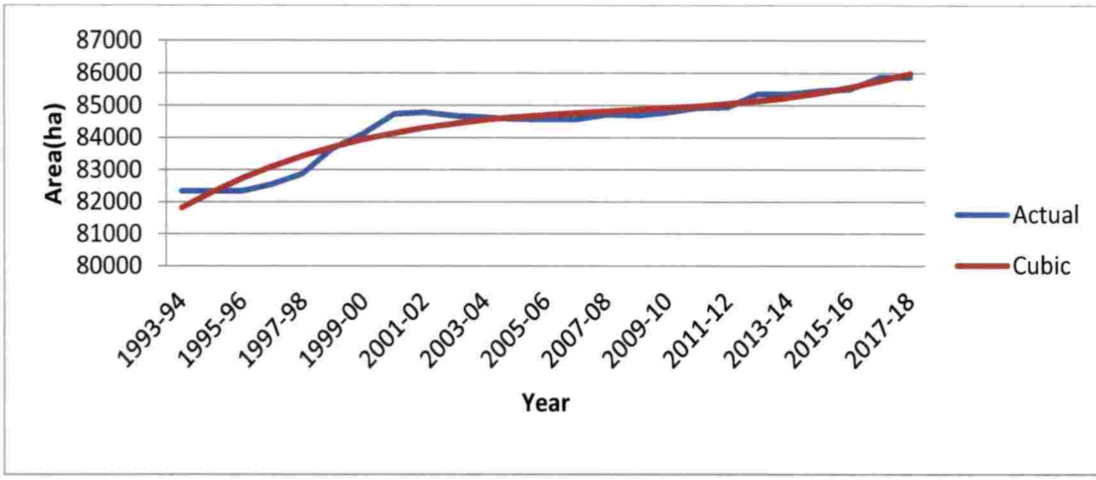

Figure 1. Actual and estimated trends in area of coffee in Kerala.

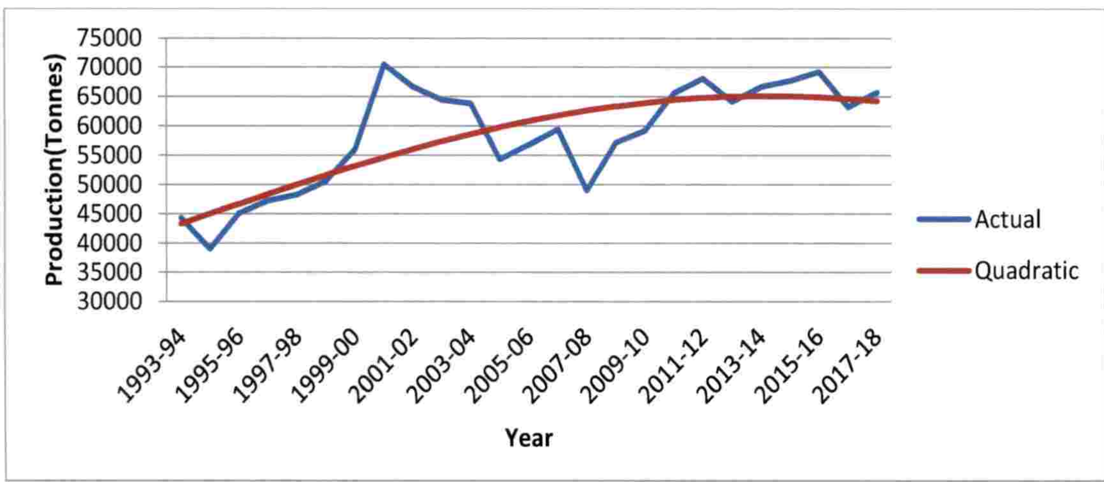

Figure 2. Actual and estimated trends in production of coffee in Kerala.

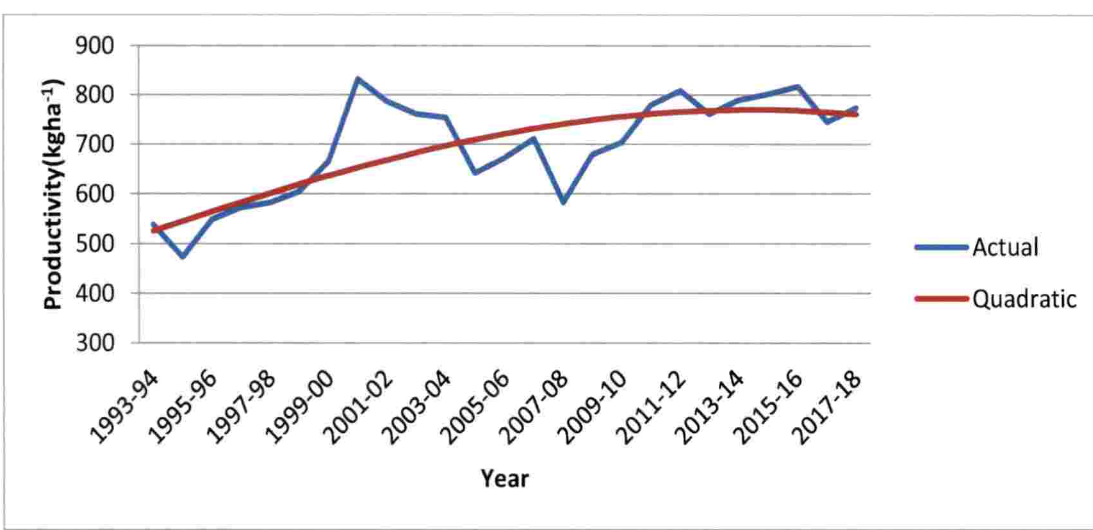

Figure 3. Actual and estimated trends in productivity of coffee in Kerala.

4.1.1.2 Trends in area, production and productivity of coffee in Karnataka

Different trend models fitted for area under coffee in Karnataka are presented in Table 6 along with adjusted R^2, Shapiro-wilk test statistic to test normality of error terms and run test for independence of error terms. The adjusted R^2 value of fitted models ranged from 62 per cent for inverse model to 97.9 per cent for cubic model. Moreover all the estimated coefficients were significant; errors were independent and normal for cubic model with highest adjusted R^2. Next to cubic model double logarithmic, quadratic and power models also had high adjusted R^2 (95.1%, 97.3% and 95.1% respectively), significant estimated coefficients and errors were normal and random. Therefore cubic model was considered as the best fitted model for trends in area under coffee in Karnataka. It is given as

$$\ln Y_t=11.879+0.054t-0.002t^2+3.558*10^{-5}t^3 \quad (\text{Adj. } R^2=0.979)$$

Shapiro-wilk test: 0.949 (p-value = 0.240)   Run test: -1.629 (p-value = 0.103)

The graph of the actual and fitted trends for area under coffee in Karnataka using cubic model is shown in Figure 4.

Different trend models fitted for production of coffee in Karnataka are presented in Table 7 along with adjusted R^2, Shapiro-wilk test statistic to test normality of error terms and run test for independence of error terms. The adjusted R^2 value of fitted models ranged from 45.2 per cent for inverse model to 77.4 per cent for cubic model. In addition, estimated coefficients were significant; errors were independent and normal for cubic model with highest adjusted R^2. Next to cubic model, double logarithmic, quadratic and power models also had high adjusted R^2 of 75.4 per cent, 75.9 per cent and 75.4 per cent respectively, significant estimated coefficients, errors were normal and random. Therefore cubic model was considered as the best fitted model for trends in production of coffee in Karnataka. The estimated model was

$$\ln Y_t=11.682+0.086t-0.005t^2+9.270*10^{-5}t^3 \quad (\text{Adj. } R^2=0.774)$$

Shapiro-wilk test: 0.162 (p-value = 0.240) Run test: -1.066 (p-value = 0.286)

The graph of the actual and fitted trends for production of coffee in Karnataka using cubic model is shown in Figure 5.

Different trend models fitted for productivity of coffee in Karnataka are presented in Table 8 along with adjusted R^2, Shapiro-wilk test statistic to test normality of error terms and run test for independence of error terms. Because of high fluctuations in the productivity, none of the fitted model was able to capture the maximum variance. The adjusted R^2 value of fitted models ranged from 9.9 per cent for inverse model to 34.2 per cent for exponential model. The estimated coefficients were significant; errors were independent and normal for exponential model. Next to exponential model semi-log, double logarithmic, quadratic and compound models also had high adjusted R^2 (31.2%, 30.5%, 32.2% and 31.2% respectively), significant estimated coefficients and, errors were normal and random. Therefore, exponential model was considered as the best fitted model for trends in productivity of coffee in Karnataka. The estimated model was given as

$$\ln Y_t = 6.765 + 0.008t \quad (\text{Adj. } R^2 = 0.342)$$

Shapiro-wilk test: 0.942 (p-value = 0.162) Run test: -0.401 (p-value = 0.688)

The graph of the actual and fitted trends for productivity of coffee in Karnataka using exponential model is given in Figure 6.

Table 6. Fitted linear and non-linear models for area of coffee in Karnataka.

	Models	Regression coefficients				Goodness of fit			F-ratio
		b_0	b_1	b_2	b_3	Adj. R^2	Shapiro-wilk test	Run test	
1	Semi-log $\ln Y = b_0 + b_1(t) + \varepsilon$	12.012** [0.019]	0.018** [0.001]			0.887	0.935 (0.113)	-4.085 (0.0001)	190.207**
2	Double logarithmic $\ln(Y) = b_0 + b_1 \ln(t) + \varepsilon$	11.868** [0.018]	0.161** [0.007]			0.951	0.929 (0.083)	-1.629 (0.103)	467.665**
3	Inverse $\ln(Y) = b_0 + \frac{b_1}{t} + \varepsilon$	12.322** [0.021]	-0.530** [0.084]			0.620	0.953 (0.289)	-4.085 (0.0001)	40.170**
4	Quadratic $\ln(Y) = b_0 + b_1(t) + b_2 t^2 + \varepsilon$	11.914** [0.015]	0.039** [0.003]	-8.36E-** [0.0001]		0.973	0.947 (0.218)	-1.629 (0.103)	435.308**
5	Cubic $\ln(Y) = b_0 + b_1(t) + b_2 t^2 + b_3 t^3 + \varepsilon$	11.879** [0.019]	0.054** [0.006]	-0.002** [0.001]	3.558E-5* [0.0001]	0.979	0.949 (0.240)	-1.629 (0.103)	367.795**
6	Compound $Y = b_0 b_1^t \varepsilon$	12.013** [0.019]	1.018** [0.001]			0.887	0.934 (0.105)	-4.085 (0.0001)	190.207**
7	Power $Y = b_0 t^{b_1} \varepsilon$	11.871** [0.018]	0.161** [0.007]			0.951	0.934 (0.109)	-1.629 (0.103)	467.665**
8	Exponential $Y = b_0 e^{(b_1 t)}$	12.013** [0.019]	0.018** [0.001]			0.887	0.934 (0.105)	-4.085 (0.0001)	190.207**

Value in ( ) - p value
*- significant at 5% level of significance

Value in [ ] – standard error
**- significant at 1% level of significance

Table 7. Fitted linear and non-linear models for production of coffee in Karnataka.

	Models	Regression coefficients				Goodness of fit			F-ratio
		b_0	b_1	b_2	b_3	Adj. R^2	Shapiro-wilk test	Run test	
1	Semi-log $\ln Y = b_0 + b_1(t) + \varepsilon$	11.891** [0.041]	0.021** [0.003]			0.697	0.964 (0.492)	-2.000 (0.046)	56.227**
2	Double logarithmic $\ln(Y) = b_0 + b_1 \ln(t) + \varepsilon$	11.720** [0.54]	0.191** [0.022]			0.754	0.955 (0.325)	-0.401 (0.688)	74.729**
3	Inverse $\ln(Y) = b_0 + \frac{b_1}{t} + \varepsilon$	12.255** [0.034]	-0.607** [0.133]			0.452	0.963 (0.469)	-2.414 (0.016)	20.773**
4	Quadratic $\ln(Y) = b_0 + b_1(t) + b_2t^2 + \varepsilon$	11.773** [0.058]	0.047** [0.01]	-0.001* [0.000]		0.759	0.951 (0.259)	-0.008 (0.993)	38.856**
5	Cubic $\ln(Y) = b_0 + b_1(t) + b_2t^2 + b_3t^3 + \varepsilon$	11.682** [0.081]	0.086** [0.026]	-0.005 [0.002]	9.27E-5 [0.0001]	0.774	0.942 (0.162)	-1.066 (0.286)	28.427**
6	Compound $Y = b_0 b_1^{\,t} \varepsilon$	11.892** [0.041]	1.021** [0.003.]			0.697	0.962 (0.465)	-2.000 (0.046)	56.227**
7	Power $Y = b_0 t^{b_1} \varepsilon$	11.723** [0.053]	0.191** [0.022]			0.754	0.955 (0.319)	-0.401 (0.688)	74.729**
8	Exponential $Y = b_0 e^{(b_1 t)}$	11.892** [0.041]	0.021**			0.697	0.962 (0.465)	-2.000 (0.046)	56.227**

Value in ( ) - p value

Value in [ ] – standard error

*- significant at 5% level of significance

**- significant at 1% level of significance

Table 8. Fitted linear and non-linear models for productivity of coffee in Karnataka.

	Models	Regression coefficients				Goodness of fit			F-ratio
		b_0	b_1	b_2	b_3	Adj. R^2	Shapiro-wilk test	Run test	
1	Semi-log $\ln Y = b_0 + b_1(t) + \varepsilon$	6.765** [0.033]	0.008** [0.002]			0.312	0.942 (0.164)	-0.401 (0.688)	13.486**
2	Double logarithmic $\ln(Y) = b_0 + b_1 \ln(t) + \varepsilon$	6.712** [0.049]	0.068** [0.020]			0.305	0.936 (0.122)	-0.401 (0.688)	11.537**
3	Inverse $\ln(Y) = b_0 + \frac{b_1}{t} + \varepsilon$	6.896** [0.023]	-0.175^{NS} [0.092]			0.099	0.962 (0.451)	-1.629 (0.103)	3.634^{NS}
4	Quadratic $\ln(Y) = b_0 + b_1(t) + b_2t^2 + \varepsilon$	6.741** [0.052]	0.013^{NS} [0.009]	0.0001^{NS} [0.0001]		0.322	0.933 (0.102)	-0.340 (0.734)	6.711**
5	Cubic $\ln(Y) = b_0 + b_1(t) + b_2t^2 + b_3t^3 + \varepsilon$	6.737** [0.077]	0.015^{NS} [0.025]	0.0001^{NS} [0.002]	4.042E-6^{NS} [0.0001]	0.290	0.930 (0.089)	-0.340 (0.734)	4.274*
6	Compound $Y = b_0 b_1{}^{t} \varepsilon$	6.764** [0.032]	1.008** [0.002]			0.312	0.942 (0.162)	-0.401 (0.688)	13.463**
7	Power $Y = b_0 t^{b_1} \varepsilon$	6.713** [0.048]	0.068** [0.020]			0.304	0.936 (0.119)	-0.401 (0.688)	11.487
8	Exponential $Y = b_0 e^{(b_1 t)}$	6.764** [0.032]	0.008** [0.002]			0.342	0.942 (0.162)	-0.401 (0.688)	13.463**

Value in ( ) - p value Value in [ ] – standard error NS- not significant

*- significant at 5% level of significance **- significant at 1% level of significance

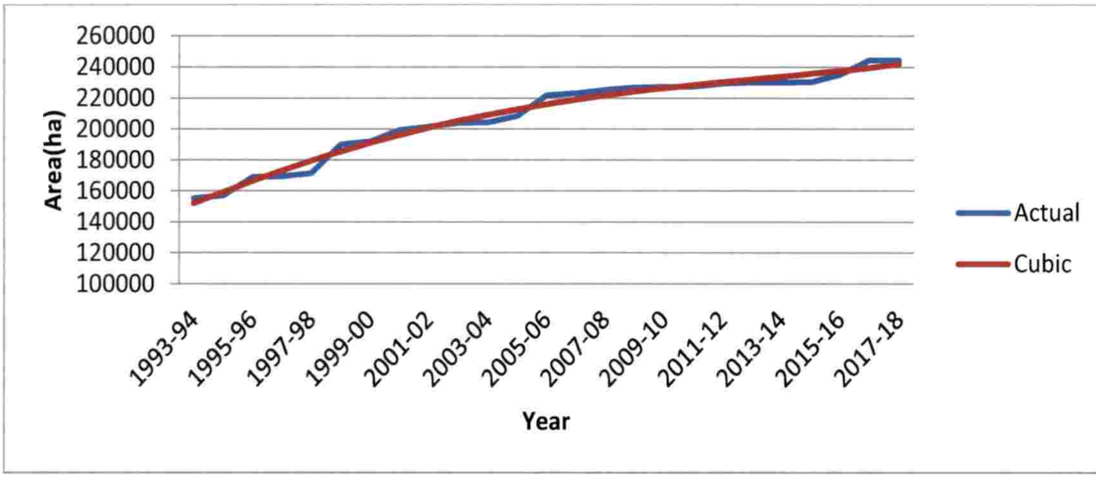

Figure 4. Actual and estimated trends in area of coffee in Karnataka.

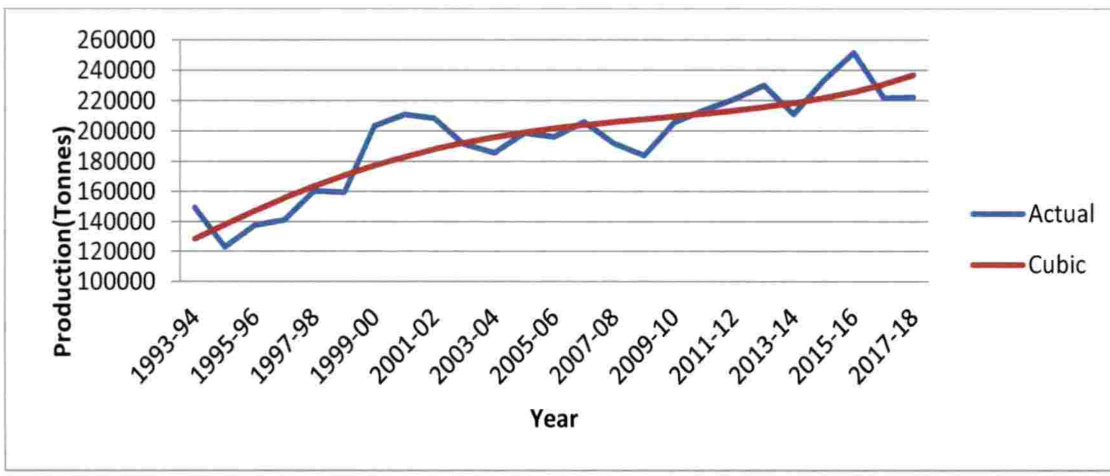

Figure 5. Actual and estimated trends in producton of coffee in Karnataka.

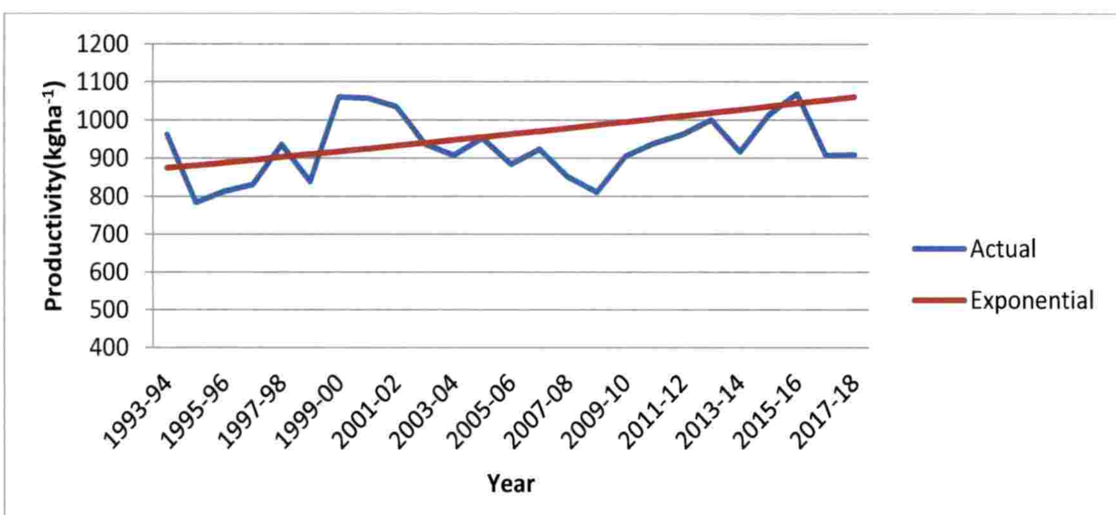

Figure 6. Actual and estimated trends in productivity of coffee in Karnataka.

4.1.1.3. Trends in area, production and productivity of coffee in Tamil Nadu

Different trend models fitted for area of coffee in Tamil Nadu are presented in Table 9 along with adjusted R^2, Shapiro-wilk test statistic to test normality of error terms and run test for independence of error terms. The adjusted R^2 value of fitted models ranged from 3.3 per cent for inverse model to 97 per cent for quadratic model. All the estimated coefficients were significant and errors were distributed normally for quadratic model with highest adjusted R^2. Next to quadratic model, cubic model was found to have high adjusted R^2 (77.7%), Gaussian errors but all the estimated coefficients were not significant. Further, errors were not random in all the fitted models. Therefore, quadratic model which satisfy all the criteria was considered as the best fitted model for trends in area under coffee in Tamil Nadu. The estimated equation was

$$\ln Y_t = 10.416 - 0.017t - 0.001t^2 \qquad (\text{Adj. } R^2 = 0.970)$$

Shapiro-wilk test: 0.959 (p-value = 0.394)   Run test: -2.772 (p-value = 0.006)

The graph of the actual and fitted trends for area under coffee in Tamil Nadu using quadratic model is shown in Figure 7.

The trend models fitted for production of coffee in Tamil Nadu are presented in Table 10 along with adjusted R^2, Shapiro-wilk test statistic to test normality of error terms and run test for independence of error terms. Because of high fluctuations and not much increase in the production of coffee in Tamil Nadu, none of model was found to be significant and also not able to capture the fluctuations in the data. The adjusted R^2 value of fitted models ranged from only 0.2 per cent for semi-log model to 12.5 per cent for quadratic model. In addition to this first two estimated coefficients were significant; errors were independent and normal for quadratic model which had highest adjusted R^2 among the fitted models. Next to quadratic model, cubic model also found to had low adjusted R^2 (8.6%), only one estimated coefficient was significant but errors were normal and random. Therefore among the fitted models quadratic model was considered as the best fitted model for trends in production of coffee in Tamil Nadu. It was given as

$$\ln Y_t = 9.664 + 0.019t - 0.0001t^2 \qquad (\text{Adj. } R^2 = 0.125)$$

Shapiro-wilk test: 0.964 (p-value = 0.496)   Run test: 0.417 (p-value = 0.676)

The graph of the actual and fitted trends for production of coffee in Tamil Nadu using quadratic model is presented in Figure 8.

Different trend models fitted for productivity of coffee in Tamil Nadu are presented in Table 11 along with adjusted R^2, Shapiro-wilk test statistic to test normality of error terms and run test for independence of error terms. Because of high fluctuations and not much increase in the productivity, none of the model was able to capture the maximum variance. The adjusted R^2 value of the fitted models ranged from 0.6 per cent for semi-log, compound and exponential model to 36.1 per cent for quadratic model. In addition, the estimated coefficients were significant; errors were independent and normal for quadratic model which had highest adjusted R^2 among the fitted models. Next to quadratic model, cubic model found to had high adjusted R^2 (33.3%), only one estimated coefficient was significant but errors were normal and random. Therefore among the fitted models quadratic model was considered as the best fitted model for trends in productivity of coffee in Tamil Nadu. The model was given as

$$\ln Y_t = 6.151 + 0.036t - 0.001\, t^2 \qquad (\text{Adj. } R^2 = 0.361)$$

Shapiro-wilk test: 0.985 (p-value = 0.958)   Run test: 0.001 (p-value = 0.986)

The graph of the actual and fitted trends for productivity of coffee in Tamil Nadu using quadratic model is depicted in Figure 9.

Table 9. Fitted linear and non-linear models for area of coffee in Tamil Nadu.

	Models	Regression coefficients				Goodness of fit			F-ratio
		b_0	b_1	b_2	b_3	Adj. R^2	Shapiro-wilk test	Run test	
1	Semi-log $\ln Y = b_0 + b_1(t) + \varepsilon$	10.328** [0.017]	0.003* [0.001]			0.171	0.692 (0.000)	-3.769 (0.000)	5.940**
2	Double logarithmic $\ln(Y) = b_0 + b_1 \ln(t) + \varepsilon$	10.344** [0.028]	0.009^{NS} [0.011			-0.016	0.727 (0.000)	-3.769 (0.000)	0.627^{NS}
3	Inverse $\ln(Y) = b_0 + \frac{b_1}{t} + \varepsilon$	10.362** [0.012]	0.022^{NS} [0.047]			-0.033	0.721 (0.000)	-3.882 (0.000)	0.226^{NS}
4	Quadratic $\ln(Y) = b_0 + b_1(t) + b_2 t^2 + \varepsilon$	10.416** [0.014]	-0.017** [0.003]	0.001** [0.0001]		0.970	0.959 (0.394)	-2.772 (0.006)	43.509**
5	Cubic $\ln(Y) = b_0 + b_1(t) + b_2 t^2 + b_3 t^3 + \varepsilon$	10.403** [0.020]	-0.011^{NS} [0.007]	0.0001^{NS} [0.001]	1.300E-5^{NS} [0.0001]	0.777	0.958 (0.377)	-3.198 (0.001)	28.932**
6	Compound $Y = b_0 b_1^t \varepsilon$	10.328** [0.017]	1.003** [0.001]			0.171	0.692 (0.000)	-3.769 (0.000)	5.940*
7	Power $Y = b_0 t^{b_1} \varepsilon$	10.344** [0.028]	0.009^{NS} [0.011]			-0.016	0.727 (0.000)	-3.769 (0.000)	0.627^{NS}
8	Exponential $Y = b_0 e^{(b_1 t)}$	10.328** [0.017]	0.003* [0.001]			0.171	0.692 (0.000)	--3.769 (0.000)	5.940*

Value in ( ) - p value Value in [ ] – standard error NS- not significant

*- significant at 5% level of significance **- significant at 1% level of significance

Table 10. Fitted linear and non-linear models for production of coffee in Tamil Nadu.

	Models	Regression coefficients				Goodness of fit			F-ratio
		b_0	b_1	b_2	b_3	Adj. R^2	Shapiro-wilk test	Run test	
1	Semi-log $\ln Y = b_0 + b_1(t) + \varepsilon$	9.741** [0.033]	0.002^{NS} [0.002]			0.002	0.943 (0.171)	0.075 (0.940)	1.052^{NS}
2	Double logarithmic $\ln(Y) = b_0 + b_1 \ln(t) + \varepsilon$	9.702** [0.06]	0.029^{NS} [0.019]			0.055	0.942 (0.162)	0.008 (0.993)	2.399^{NS}
3	Inverse $\ln(Y) = b_0 + \frac{b_1}{t} + \varepsilon$	9.785** [0.020]	- 0.101^{NS} [0.077]			0.029	0.957 (0.352)	0.008 (0.993)	1.721^{NS}
4	Quadratic $\ln(Y) = b_0 + b_1(t) + b_2t^2 + \varepsilon$	9.664** [0.048]	0.019* [0.009]	0.0001^{NS} [0.0001]		0.125	0.964 (0.496)	0.417 (0.676)	2.717^{NS}
5	Cubic $\ln(Y) = b_0 + b_1(t) + b_2t^2 + b_3t^3 + \varepsilon$	9.651** [0.071]	0.025^{NS} [0.023]	-0.001 [0.002]	1.32E-5^{NS} [0.0001]	0.086	0.966 (0.550)	1.236 (0.216)	1.756^{NS}
6	Compound $Y = b_0 b_1^t \varepsilon$	9.740** [0.032]	1.002** [0.002]			0.002	0.942 (0.169)	0.075 (0.940)	1.052^{NS}
7	Power $Y = b_0 t^{b_1} \varepsilon$	9.702** [0.046]	0.029^{NS} [0.019]			0.055	0.942 (0.161)	0.008 (0.993)	2.399^{NS}
8	Exponential $Y = b_0 e^{(b_1 t)}$	9.740** [0.032]	0.002^{NS} [0.002]			0.002	0.942 (0.169)	0.075 (0.940)	1.052^{NS}

Value in ( ) - p value Value in [ ] – standard error NS- not significant

*- significant at 5% level of significance **- significant at 1% level of significance

Table 11. Fitted linear and non-linear models for productivity of coffee in Tamil Nadu.

	Models	Regression coefficients				Goodness of fit			F-ratio
		b_0	b_1	b_2	b_3	Adj. R^2	Shapiro-wilk test	Run test	
1	Semi-log $\ln Y = b_0 + b_1(t) + \varepsilon$	6.303** [0.041]	0.003^{NS} [0.003]			-0.006	0.979 (0.869)	-0.755 (0.450)	0.862^{NS}
2	Double logarithmic $\ln(Y) = b_0 + b_1 \ln(t) + \varepsilon$	6.236** [0.057]	0.043^{NS} [0.023]			0.093	0.976 (0.794)	0.075 (0.940)	3.467^{NS}
3	Inverse $\ln(Y) = b_0 + \frac{b_1}{t} + \varepsilon$	6.364** [0.024]	-0.181^{NS} [0.093]			0.103	0.974 (0.738)	-0.213 (0.831)	3.751^{NS}
4	Quadratic $\ln(Y) = b_0 + b_1(t) + b_2 t^2 + \varepsilon$	6.151** [0.052]	0.036** [0.009]	-0.001** [0.0001]		0.361	0.985 (0.958)	0.001 (0.986)	7.789**
5	Cubic $\ln(Y) = b_0 + b_1(t) + b_2 t^2 + b_3 t^3 + \varepsilon$	6.167** [0.076]	0.030^{NS} [0.025]	0.0001^{NS} [0.002]	$-1.589E\text{-}5^{NS}$ [0.000]	0.333	0.983 (0.944)	0.490 (0.624)	5.003**
6	Compound $Y = b_0 b_1^{\,t} \varepsilon$	6.302** [0.041]	1.003** [0.003]			-0.006	0.979 (0.871)	-0.755 (0.450)	0.867^{NS}
7	Power $Y = b_0 t^{b_1} \varepsilon$	6.235** [0.056]	0.043^{NS} [0.023]			0.094	0.976 (0.796)	0.075 (0.940)	3.481^{NS}
8	Exponential $Y = b_0 e^{(b_1 t)}$	6.302** [0.041]	0.003^{NS} [0.003]			-0.006	0.979 (0.871)	-0.755 (0.450)	0.867^{NS}

Value in ( ) - p value Value in [ ] – standard error NS- not significant
*- significant at 5% level of significance **- significant at 1% level of significance

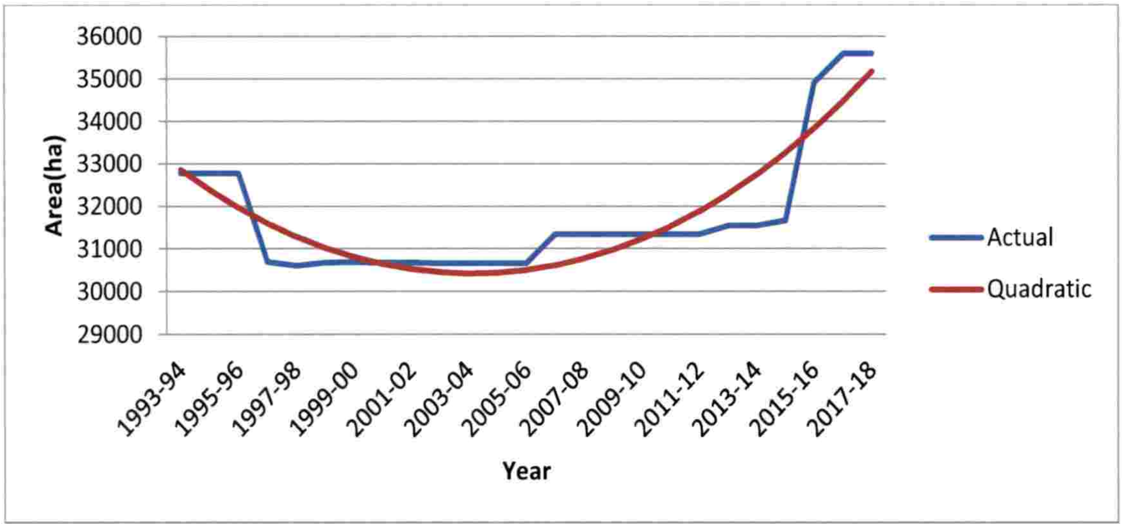

Figure 7. Actual and estimated trends in area of coffee in Tamil Nadu.

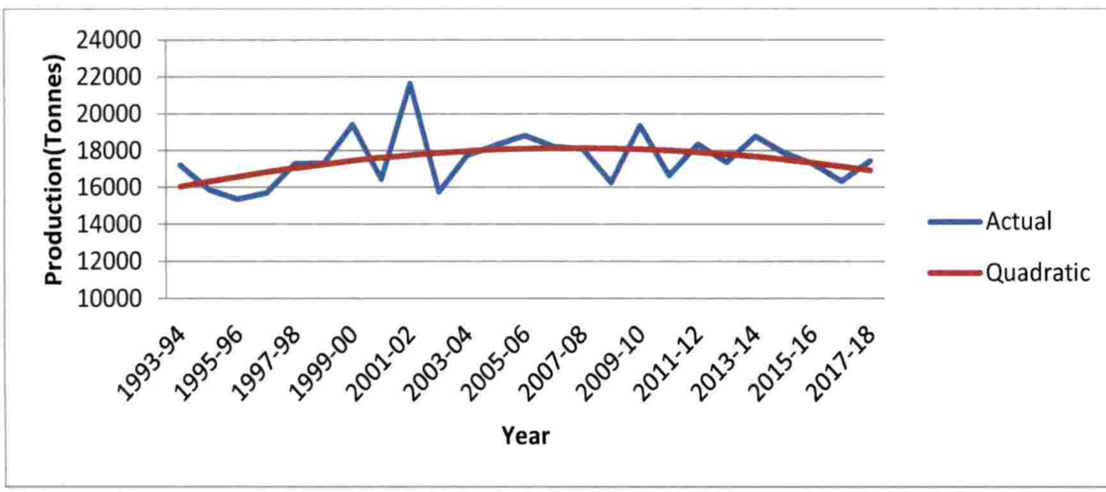

Figure 8. Actual and estimated trends in production of coffee in Tamil Nadu.

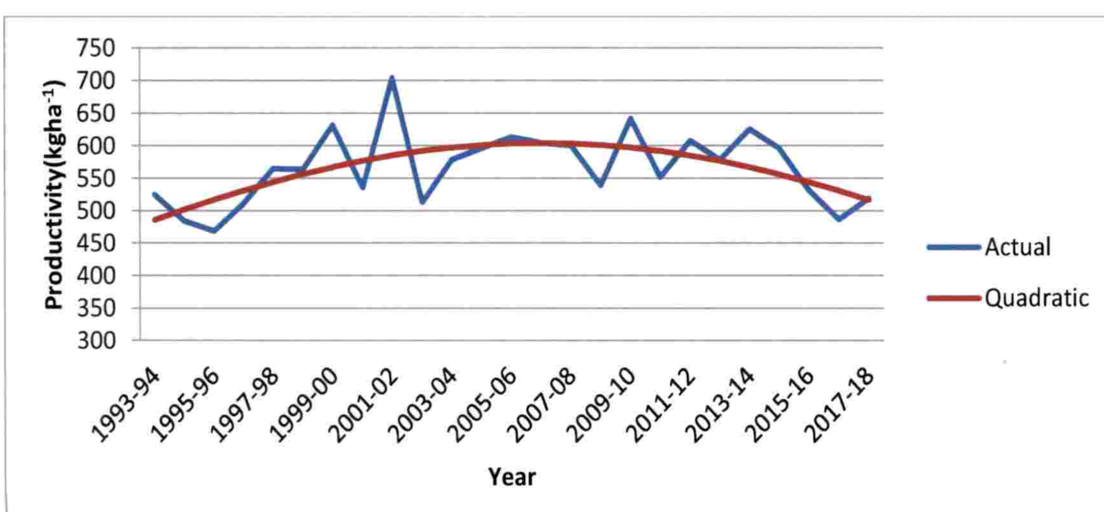

Figure 9. Actual and estimated trends in productivity of coffee in Tamil Nadu.

4.1.2 Cardamom

Eight different growth models were fitted to study the trends in area, production and productivity of cardamom in South Indian states Kerala, Karnataka and Tamil Nadu. The results of fitted models are presented with discussions.

4.1.2.1 Trends in area, production and productivity of cardamom in Kerala

Different trend models fitted for area under cardamom in Kerala are presented in Table 12 along with adjusted R^2, Shapiro-wilk test statistic to test normality of error terms and run test for independence of error terms. The adjusted R^2 value of the fitted models ranged from 36.4 per cent for inverse model to 75.6 per cent for cubic model. The estimated coefficients were significant; errors were independent and normal for cubic model which had highest adjusted R^2. Next to cubic model, semi-log, compound and exponential models also found to had high adjusted R^2 (71.9%), significant estimated coefficients and errors were normal and random. Therefore, cubic model was considered as the best fitted model for trends in area under cardamom in Kerala. The model was given as

$$\ln Y_t=10.717-0.015t-0.001t^2-1.93*10^{-5}t^3 \qquad (\text{Adj. } R^2=0.756)$$

Shapiro-wilk test: 0.949 (p-value = 0.240) Run test: -1.629 (p-value = 0.103)

The graph of the actual and fitted trends for area under cardamom in Kerala using cubic model is presented in Figure 10.

The trend models fitted for production of cardamom in Kerala are presented in Table 13 along with adjusted R^2, Shapiro-wilk test statistic to test normality of error terms and run test for independence of error terms. The adjusted R^2 value of the fitted models ranged from 39 per cent for inverse model to 89 per cent for the cubic model. The estimated coefficients were significant; errors were independent and normal for cubic model which had highest adjusted R^2. Next to cubic model, semi-log, compound and exponential models also found to had high adjusted R^2 (87.1%), significant estimated coefficients and errors were normal and random. Therefore, cubic model was considered as the best fitted model for trends in production of cardamom in Kerala. The model was given as

$\ln Y_t$=7.786+0.169t-0.009t^2+0.0001t^3 (Adj. R^2=0.890)

Shapiro-wilk test: 0.949 (p-value = 0.240) Run test: -1.29(p-value = 0.103)

The graph of the actual and fitted trends for production of cardamom in Kerala using cubic model is shown in Figure 11.

The trend models fitted for productivity of cardamom in Kerala are presented in Table 14 along with adjusted R^2, Shapiro-wilk test statistic to test normality of error terms and run test for independence of error terms. The adjusted R^2 value of fitted models ranged from 4.6 per cent for inverse model to 93.2 per cent for cubic model. The estimated coefficients were significant; errors were independent and normal for cubic model which had highest adjusted R^2. Next to cubic model, semi-log (89.5%), quadratic (90.1%), compound (89.1%) and exponential (89.1%) models also found to have high adjusted R^2, significant estimated coefficients and errors were normal and random. Therefore cubic model was considered as the best fitted model for trend in productivity of cardamom in Kerala. The model was given as

$\ln Y_t$=4.101+0.2159t-0.011t^2+0.0001t^3 (Adj. R^2=0.932)

Shapiro-wilk test: 0.949 (p-value = 0.240) Run test: -1.629 (p-value = 0.103)

The graph of the actual and fitted trends for productivity of cardamom in Kerala using cubic model is shown in Figure 12.

Table 12. Fitted linear and non-linear models for area of cardamom in Kerala.

	Models	Regression coefficients				Goodness of fit			F-ratio
		b_0	b_1	b_2	b_3	Adj. R^2	Shapiro-wilk test	Run test	
1	Semi-log $\ln Y = b_0 + b_1(t) + \varepsilon$	10.685** [0.007]	-0.004** [0.0001]			0.719	0.935 (0.113)	-4.085 (0.0001)	69.989**
2	Double logarithmic $\ln(Y) = b_0 + b_1 \ln(t) + \varepsilon$	10.717** [0.012]	-0.035** [0.005]			0.673	0.929 (0.083)	-1.629 (0.103)	56.505**
3	Inverse $\ln(Y) = b_0 + \frac{b_1}{t} + \varepsilon$	10.615** [0.007]	0.113** [0.028]			0.364	0.953 (0.289)	-4.085 (0.0001)	16.476**
4	Quadratic $\ln(Y) = b_0 + b_1(t) + b_2 t^2 + \varepsilon$	10.691** [0.012]	-0.005* [0.002]	3.64E-5^{NS} [0.0001]		0.711	0.947 (0.218)	-1.629 (0.103)	34.269**
5	Cubic $\ln(Y) = b_0 + b_1(t) + b_2 t^2 + b_3 t^3 + \varepsilon$	10.717** [0.015]	-0.015** [0.005]	0.001* [0.0001]	-1.93E-5* [0.0001]	0.756	0.949 (0.240)	-1.629 (0.103)	28.909**
6	Compound $Y = b_0 b_1^{t} \varepsilon$	10.685** [0.007]	0.996** [0.0001]			0.719	0.934 (0.105)	-4.085 (0.0001)	69.988**
7	Power $Y = b_0 t^{b_1} \varepsilon$	10.717** [0.012]	-0.035** [0.005]			0.673	0.934 (0.109)	-1.629 (0.103)	56.504**
8	Exponential $Y = b_0 e^{(b_1 t)}$	10.685 [0.007]	-0.004** [0.0001]			0.719	0.934 (0.105)	-4.085 (0.0001)	69.988**

Value in ( ) - p value Value in [ ] – standard error NS- not significant

*- significant at 5% level of significance **- significant at 1% level of significance

Table 13. Fitted linear and non-linear models for production of cardamom in Kerala.

	Models	Regression coefficients				Goodness of fit			F-ratio
		b_0	b_1	b_2	b_3	Adj. R^2	Shapiro-wilk test	Run test	
1	Semi-log $\ln Y = b_0 + b_1(t) + \varepsilon$	8.081** [0.073]	0.060** [0.004]			0.871	0.935 (0.113)	-4.085 (0.0001)	183.139**
2	Double logarithmic $\ln(Y) = b_0 + b_1 \ln(t) + \varepsilon$	7.616** [0.147]	0.549** [0.057]			0.771	0.929 (0.083)	-1.629 (0.103)	91.662**
3	Inverse $\ln(Y) = b_0 + \frac{b_1}{t} + \varepsilon$	9.187** [0.096]	-1.70** [0.399]			0.390	0.953 (0.289)	-4.085 (0.0001)	18.283**
4	Quadratic $\ln(Y) = b_0 + b_1(t) + b_2 t^2 + \varepsilon$	8.061** [0.117]	0.064** [0.019]	.0001^{NS} [0.001]		0.866	0.947 (0.218)	-1.629 (0.103)	88.240**
5	Cubic $\ln(Y) = b_0 + b_1(t) + b_2 t^2 + b_3 t^3 + \varepsilon$	7.786** [0.151]	0.169** [0.044]	-0.009* [0.004]	0.0001* [0.001]	0.890	0.949 (0.240)	-1.629 (0.103)	74.031**
6	Compound $Y = b_0 b_1^{t} \varepsilon$	8.106** [0.067]	1.062** [0.005]			0.871	0.934 (0.105)	-4.085 (0.0001)	183.139**
7	Power $Y = b_0 t^{b_1} \varepsilon$	7.682** [0.122]	0.549** [0.057]			0.771	0.934 (0.109)	-1.629 (0.103)	91.662**
8	Exponential $Y = b_0 e^{(b_1 t)}$	8.106** [0.067]	0.060** [0.004]			0.871	0.934 (0.105)	-4.085 (0.0001)	183.139**

Value in ( ) - p value   Value in [ ] – standard error   NS- not significant

*- significant at 5% level of significance   **- significant at 1% level of significance

Table 14. Fitted linear and non-linear models for productivity of cardamom in Kerala.

	Models	Regression coefficients				Goodness of fit			F-ratio
		b_0	b_1	b_2	b_3	Adj. R^2	Shapiro-wilk test	Run test	
1	Semi-log $\ln Y = b_0 + b_1(t) + \varepsilon$	4.560** [0.071]	0.065** [0.004]			0.895	0.935 (0.113)	-4.085 (0.0001)	230.426**
2	Double logarithmic $\ln(Y) = b_0 + b_1 \ln(t) + \varepsilon$	3.995** [0.124]	0.622** [0.08]			0.859	0.929 (0.083)	-1.629 (0.103)	165.607**
3	Inverse $\ln(Y) = b_0 + \frac{b_1}{t} + \varepsilon$	5.791** [0.094]	- 2.047** [0.390]			0.496	0.953 (0.289)	-4.085 (0.0001)	27.544**
4	Quadratic $\ln(Y) = b_0 + b_1(t) + b_2 t^2 + \varepsilon$	4.422** [0.108]	0.093** [0.017]	0.0001^{NS} [0.001]		0.901	0.947 (0.218)	-1.629 (0.103)	124.214**
5	Cubic $\ln(Y) = b_0 + b_1(t) + b_2 t^2 + b_3 t^3 + \varepsilon$	4.101** [0.128]	0.215** [0.038]	-0.011** [0.003]	0.0001** [0.0001]	0.932	0.949 (0.240)	-1.629 (0.103)	124.370**
6	Compound $Y = b_0 b_1^{\,t} \varepsilon$	4.598** [0.065]	1.067** [0.005]			0.895	0.934 (0.105)	-4.085 (0.0001)	231.481**
7	Power $Y = b_0 t^{b_1} \varepsilon$	4.117** [0.086]	0.622** [0.048]			0.859	0.934 (0.109)	-1.629 (0.103)	165.774**
8	Exponential $Y = b_0 e^{(b_1 t)}$	4.598** [0.065]	.065** [0.004]			0.895	0.934 (0.105)	-4.085 (0.0001)	231.481**

Value in ( ) - p value Value in [ ] – standard error NS- not significant

*- significant at 5% level of significance **- significant at 1% level of significance

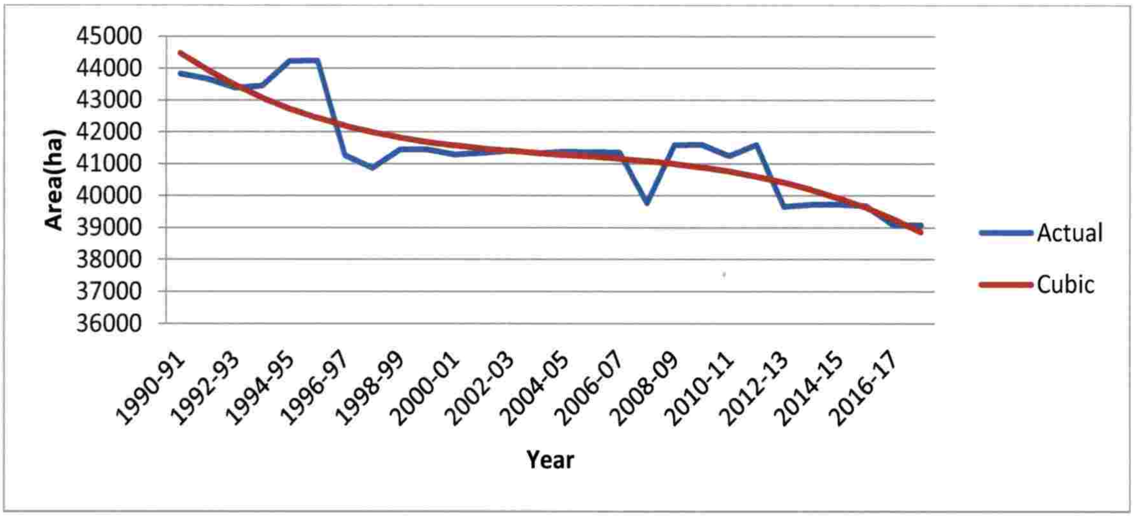

Figure 10. Actual and estimated trends in area of cardamom in Kerala.

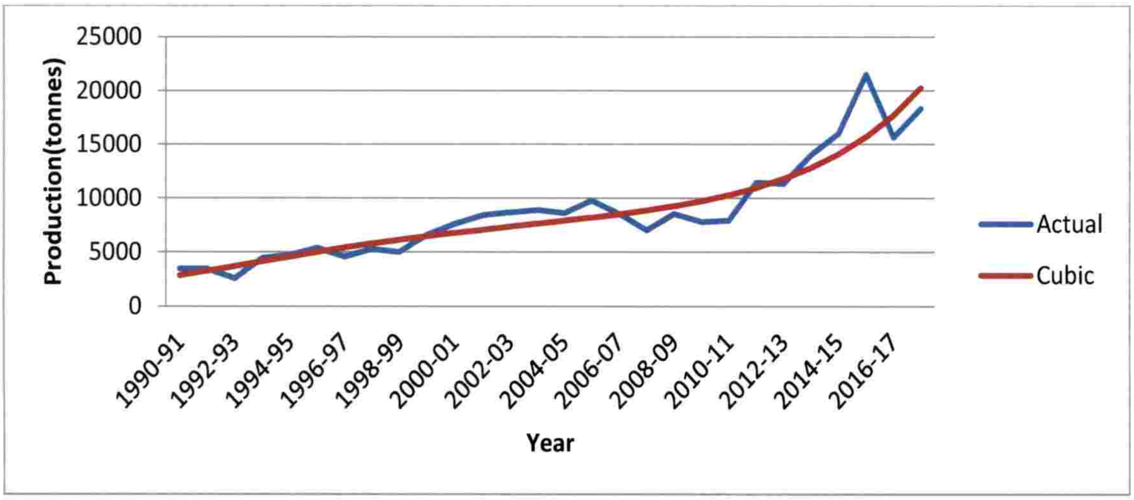

Figure 11. Actual and estimated trends in production of cardamom in Kerala.

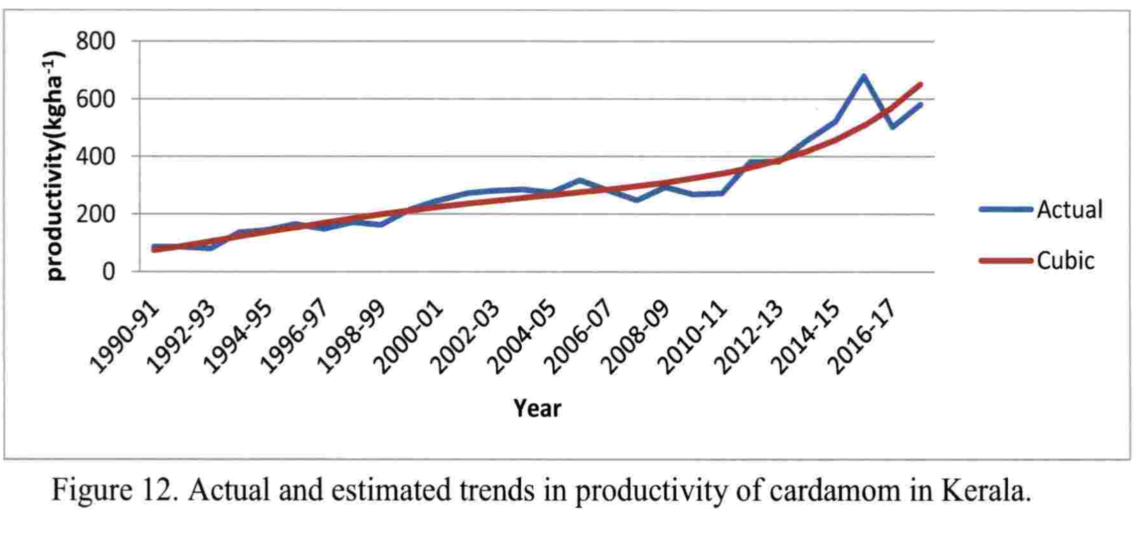

Figure 12. Actual and estimated trends in productivity of cardamom in Kerala.

4.1.2.2 Trends in area, production and productivity of cardamom in Karnataka

The trend models fitted for area under cardamom in Karnataka are presented in Table 15 along with adjusted R^2, Shapiro-wilk test statistic to test normality of error terms and run test for independence of error terms. The adjusted R^2 value of fitted models ranged from 38.7 per cent for inverse model to 70.5 per cent for quadratic model. The estimated coefficients were significant; errors were independent (at 5 per cent level of significance only) and normal for quadratic model which had highest adjusted R^2. Next to quadratic model, double logarithmic, cubic and power models also found to had high adjusted R^2 (66.6%, 70% and 66.6% respectively), significant estimated coefficients, errors were normal but not random. Therefore quadratic model was considered as the best fitted model for trends in area under cardamom in Karnataka. The model was given as

$$\ln Y_t = 10.446 - 0.029t + 0.001t^2 \qquad (\text{Adj. } R^2 = 0.705)$$

Shapiro-wilk test: 0.964 (p-value = 0.431) Run test: -2.118 (p-value = 0.034)

The graph of the actual and fitted trends for area under cardamom in Karnataka using quadratic model is shown in Figure 13.

The trend models fitted for production of cardamom in Karnataka are presented in Table 16 along with adjusted R^2, Shapiro-wilk test statistic to test for the normality of error terms and run test for independence of error terms. The adjusted R^2 value of the fitted models ranged from 1.7 per cent for semi-log, compound and exponential models to 58 per cent for cubic model. The estimated coefficients were significant; errors were independent and normal for cubic model with highest adjusted R^2. Further quadratic model also had high adjusted R^2 (50.2%), significant estimated coefficients and, errors were normal and random. However, in models such as semi-log, quadratic and compound models coefficients were significant, adjusted R^2 values were less than that of cubic model. Therefore cubic model was considered as the best fitted model for trends in production of cardamom in Karnataka. The model was given as

$\ln Y_t = 6.606+0.187t-0.011t^2+0.0001t^3$ (Adj. R^2=0.580)

Shapiro-wilk test: 0.940 (p-value = 0.110) Run test: -1.658(p-value = 0.097)

The graph of the actual and fitted trends for production of cardamom in Karnataka using cubic model is given in Figure 14.

Different trend models fitted for productivity of cardamom in Karnataka are presented in Table 17 along with adjusted R^2, Shapiro-wilk test statistic to test normality of error terms and run test for independence of error terms. The adjusted R^2 value of the fitted models ranged from 13.9 per cent for compound and exponential models to 65.5 per cent for cubic model. In addition to that, the estimated coefficients were significant; errors were independent and normal for cubic model. Highest adjusted R^2 was observed for this model. Next to cubic model, quadratic model also had high adjusted R^2 (60.4%), significant estimated coefficients and, errors were normal and random. But on a comparative basis cubic model was considered as the best fitted model for trends in productivity of cardamom in Karnataka. The model was given as

$\ln Y_t=3.478+0.195t-0.011t^2+0.0001t^3$ (Adj. R^2=0.655)

Shapiro-wilk test: 0.949 (p-value = 0.240) Run test:-1.629 (p-value = 0.103)

The graph of the actual and fitted trends for productivity of cardamom in Karnataka using cubic model is shown in Figure 15.

Table 15. Fitted linear and non-linear models for area of cardamom in Karnataka.

	Models	Regression coefficients				Goodness of fit			F-ratio
		b_0	b_1	b_2	b_3	Adj. R^2	Shapiro-wilk test	Run test	
1	Semi-log $\ln Y = b_0 + b_1(t) + \varepsilon$	10.352** [0.027]	-0.010** [0.002]			0.580	0.975 (0.723)	-3.651 (0.000)	38.304
2	Double logarithmic $\ln(Y) = b_0 + b_1 \ln(t) + \varepsilon$	10.458** [0.036]	-0.104** [0.014]			0.666	0.939 (0.105)	-3.264 (0.001)	54.725
3	Inverse $\ln(Y) = b_0 + \frac{b_1}{t} + \varepsilon$	10.159** [0.019]	0.343** [0.081]			0.387	0.785 (0.000)	-3.517 (0.000)	18.020
4	Quadratic $\ln(Y) = b_0 + b_1(t) + b_2 t^2 + \varepsilon$	10.446** [0.035]	-0.029** [0.006]	0.001** [0.000]		0.705	0.964 (0.431)	-2.118 (0.034)	33.205
5	Cubic $\ln(Y) = b_0 + b_1(t) + b_2 t^2 + b_3 t^3 + \varepsilon$	10.473** [0.051]	-0.039* [0.015]	0.002^{NS} [0.001]	$-2.05E-5^{NS}$ [0.000]	0.700	0.958 (0.317)	-2.369 (0.018)	21.970
6	Compound $Y = b_0 b_1^{t} \varepsilon$	10.351** [0.027]	0.990** [0.002]			0.580	0.975 (0.716)	3.651 (0.000)	38.304**
7	Power $Y = b_0 t^{b_1} \varepsilon$	10.460** [0.037]	-0.104** [0.014]			0.666	0.939 (0.106)	--3.264 (0.001	54.725**
8	Exponential $Y = b_0 e^{(b_1 t)}$	10.351** [0.027]	-0.010** [0.002]			0.580	0.975 (0.716)	-3.651 (0.000)	38.304**

Value in ( ) - p value Value in [ ] – standard error NS- not significant
*- significant at 5% level of significance **- significant at 1% level of significance

Table 16. Fitted linear and non-linear models for production of cardamom in Karnataka.

	Models	Regression coefficients				Goodness of fit			F-ratio
		b_0	b_1	b_2	b_3	Adj. R^2	Shapiro-wilk test	Run test	
1	Semi-log $\ln Y = b_0 + b_1(t) + \varepsilon$	7.297** [0.100]	0.004 [0.006]			-0.017	0.955 (0.264)	-1.265 (0.206)	0.551^{NS}
2	Double logarithmic $\ln(Y) = b_0 + b_1 \ln(t) + \varepsilon$	7.046** [0.137]	0.130* [0.053]			0.155	0.960 (0.353)	-1.265 (0.206)	5.951*
3	Inverse $\ln(Y) = b_0 + \frac{b_1}{t} + \varepsilon$	7.473** [0.047]	-0.797** [0.198]			0.361	0.944 (0.140)	-0.751 (0.453)	16.247**
4	Quadratic $\ln(Y) = b_0 + b_1(t) + b_2t^2 + \varepsilon$	6.849** [0.110]	0.094** [0.017]	-0.003** [0.001]		0.502	0.969 (0.556)	-1.715 (0.086)	14.600**
5	Cubic $\ln(Y) = b_0 + b_1(t) + b_2t^2 + b_3t^3 + \varepsilon$	6.606** [0.143]	0.187** [0.042]	-0.011** [0.003]	0.0001* [0.000]	0.580	0.940 (0.110)	-1.658 (0.097)	13.450**
6	Compound $Y = b_0 b_1^{\,t} \varepsilon$	7.290** [0.100]	1.004** [0.006]			-0.017	0.955 (0.263)	-1.265 (0.206)	0.551^{NS}
7	Power $Y = b_0 t^{b_1} \varepsilon$	7.039** [0.132]	0.130* [0.053]			0.155	0.960 (0.354)	-1.328 (0.184)	5.950*
8	Exponential $Y = b_0 e^{(b_1 t)}$	7.290** [0.100]	0.004^{NS} [0.006]			-0.017	0.955 (0.263)	-1.265 (0.206)	0.551^{NS}

Value in ( ) - p value   Value in [ ] – standard error   NS- not significant

*- significant at 5% level of significance   **- significant at 1% level of significance

Table 17. Fitted linear and non-linear models for productivity of cardamom in Karnataka.

	Models	Regression coefficients				Goodness of fit			F-ratio
		b_0	b_1	b_2	b_3	Adj. R^2	Shapiro-wilk test	Run test	
1	Semi-log $\ln Y = b_0 + b_1(t) + \varepsilon$	4.177** [0.103]	0.015* [0.006]			0.142	0.935 (0.113)	-4.085 (0.0001)	5.484*
2	Double logarithmic $\ln(Y) = b_0 + b_1 \ln(t) + \varepsilon$	3.859** [0.130]	0.218** [0.051]			0.391	0.929 (0.083)	-1.629 (0.103)	18.327**
3	Inverse $\ln(Y) = b_0 + \frac{b_1}{t} + \varepsilon$	4.526** [0.050]	- 0.988** [0.207]			0.447	0.953 (0.289)	-4.085 (0.0001)	22.846**
4	Quadratic $\ln(Y) = b_0 + b_1(t) + b_2t^2 + \varepsilon$	3.703** [0.110]	0.109** [0.017]	-0.003** [0.001]		0.604	0.947 (0.218)	-1.629 (0.103)	21.617**
5	Cubic $\ln(Y) = b_0 + b_1(t) + b_2t^2 + b_3t^3 + \varepsilon$	3.478** [0.146]	0.195** [0.043]	-0.011** [0.003]	0.0001* [0.0001]	0.655	0.949 (0.240)	-1.629 (0.103)	18.059**
6	Compound $Y = b_0 b_1^t \varepsilon$	4.163** [0.099]	1.014** [0.006]			0.139	0.934 (0.105)	-4.085 (0.0001)	5.537*
7	Power $Y = b_0 t^{b_1} \varepsilon$	3.858** [0.115]	0.217** [0.051]			0.387	0.934 (0.109)	-1.629 (0.103)	18.011**
8	Exponential $Y = b_0 e^{(b_1 t)}$	4.163** [0.099]	0.014* [0.06]			0.139	0.934 (0.105)	-4.085 (0.0001)	5.357*

Value in ( ) - p value
*- significant at 5% level of significance

Value in [ ] – standard error
**- significant at 1% level of significance

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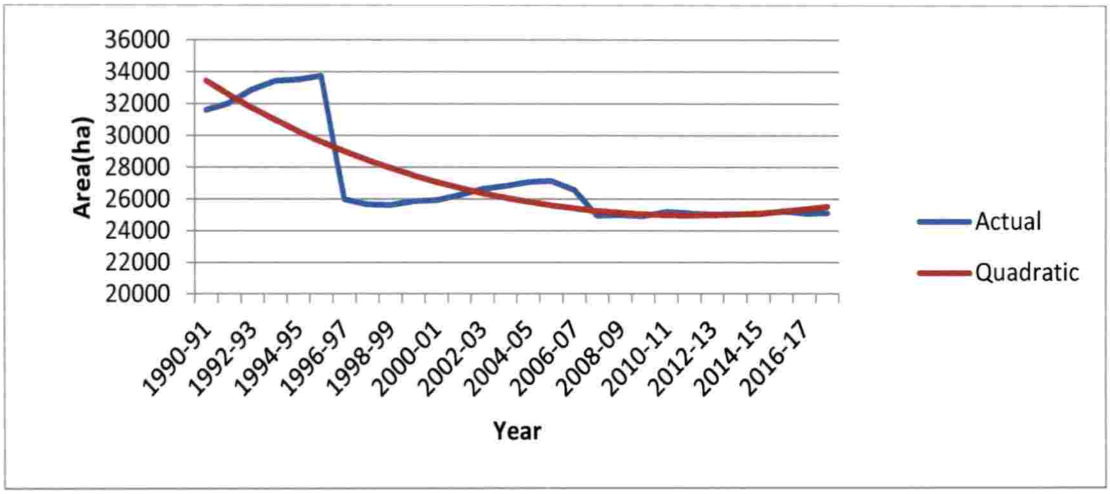

Figure 13. Actual and estimated trends in area of cardamom in Karnataka.

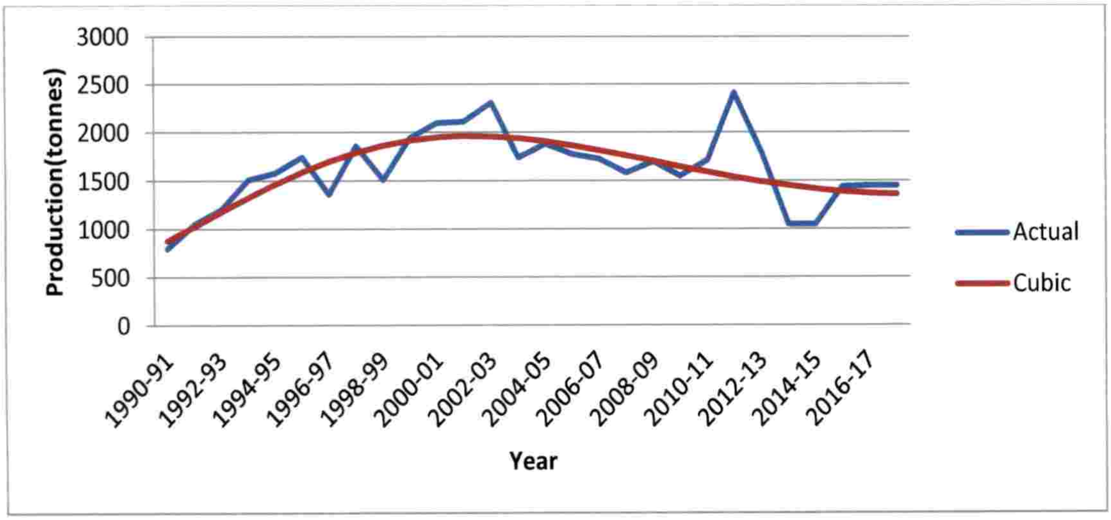

Figure 14. Actual and estimated trends in production of cardamom in Karnataka.

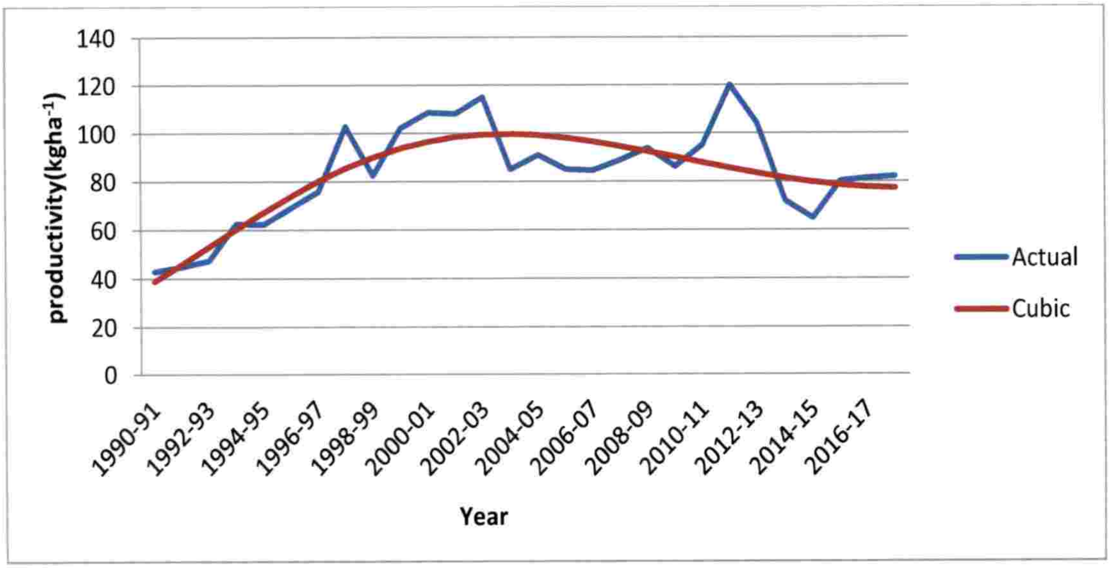

Figure 15. Actual and estimated trends in productivity of cardamom in Karnataka.

4.1.2.3. Trends in area, production and productivity of cardamom in Tamil Nadu

The fitted models for area under cardamom in Tamil Nadu are presented in Table 18 along with adjusted R^2, Shapiro-wilk test statistic to test normality of error terms and run test for independence of error terms. The adjusted R^2 value of fitted models ranged from 3.6 per cent for inverse model to 73.1 per cent for cubic model. The estimated coefficients of the cubic model were significant and errors were independent and normal. Next to cubic model, quadratic model also had high adjusted R^2 (70.4%), significant estimated coefficients and, errors were normal and random. Therefore cubic model was considered as the best fitted model for trends in area under cardamom in Tamil Nadu. The model was given as

$$\ln Y_t = 8.751-0.009t-0.001t^2+4.459*10^{-5}t^3 \qquad (\text{Adj. } R^2=0.731)$$

Shapiro-wilk test: 0.949 (p-value = 0.240)   Run test: -1.629 (p-value = 0.103)

The graph of the actual and fitted trends for area under cardamom in Tamil Nadu using cubic model is presented in Figure 16.

Different trend models fitted for production of cardamom in Tamil Nadu are presented in Table 19 along with adjusted R^2, Shapiro-wilk test statistic to test normality of error terms and run test for independence of error terms. The adjusted R^2 value of fitted models ranges from 48.8 per cent for semi-log, compound and exponential models to 70.9 per cent for cubic model. The estimated coefficients of cubic model were significant, errors were independent and normal. Next to cubic model, double logarithmic, quadratic and power models also had high adjusted R^2 (68.1%, 68.3% and 68.1% respectively), estimated coefficients were significant and, errors were normal and random, but errors were not random in the remaining models. Therefore cubic model was considered as the best fitted model for trends in production of cardamom in Tamil Nadu. The model was given as

$$\ln Y=6.043+0.114t-0.006t^2+9.62*10^{-5}t^3 \qquad (\text{Adj. } R^2=0.709)$$

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Shapiro-wilk test: 0.949 (p-value = 0.240) Run test: -1.629 (p-value = 0.103)

The graph of the actual and fitted trends for production of cardamom in Tamil Nadu using cubic model is depicted in Figure 17.

Different trend models fitted for productivity of cardamom in Tamil Nadu are presented in Table 20 along with adjusted R^2, Shapiro-wilk test statistic to test normality of error terms and run test for independence of error terms. The adjusted R^2 value of fitted models ranges from 56.7 per cent for inverse model to 86 per cent for quadratic model. The estimated coefficients of quadratic model were found to be significant; errors were independent and normally distributed with highest adjusted R^2. Next to quadratic model, double logarithmic, cubic and power models also had high adjusted R^2 (80.7%, 85.5% and 80.6% respectively), estimated coefficients were significant and, errors were normal and random. But errors were not random in the remaining models. Therefore, quadratic model was considered as the best fitted model for trends in productivity of cardamom in Tamil Nadu. The model was given as

$$\ln Y = 4.676 + 0.087t - 0.002t^2 \qquad (\text{Adj. } R^2 = 0.860)$$

Shapiro-wilk test: 0.947 (p-value = 0.218) Run test: -1.629 (p-value = 0.103)

The graph of the actual and fitted trends for productivity of cardamom in Tamil Nadu using quadratic model depicted in Figure 18.

From this study it is inferred that among the several fitted linear and non-linear models quadratic and cubic models were found to be best fit for projecting trend in area, production and productivity of both coffee and cardamom in Kerala, Karnataka and Tamil Nadu. These results are in harmony with the results obtained by Sharath (2016) who analysed the trends in area, production, productivity, and cost of cultivation and price of banana in Kerala.

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Table 18. Fitted linear and non-linear models for area of cardamom in Tamil Nadu.

	Models	Regression coefficients				Goodness of fit			F-ratio
		b_0	b_1	b_2	b_3	Adj. R^2	Shapiro-wilk test	Run test	
1	Semi-log $\ln Y = b_0 + b_1(t) + \varepsilon$	8.696** [0.028]	-0.009** [0.002]			0.488	0.935 (0.113)	-4.085 (0.0001)	26.700**
2	Double logarithmic $\ln(Y) = b_0 + b_1 \ln(t) + \varepsilon$	8.793** [0.038]	-0.092** [0.015]			0.584	0.929 (0.083)	-1.629 (0.103)	38.932**
3	Inverse $\ln(Y) = b_0 + \frac{b_1}{t} + \varepsilon$	8.526** [0.019]	0.309** [0.079]			0.346	0.953 (0.289)	-4.085 (0.0001)	15.263**
4	Quadratic $\ln(Y) = b_0 + b_1(t) + b_2 t^2 + \varepsilon$	8.811** [0.033]	-0.032** [0.005]	0.001** [0.0001]		0.704	0.947 (0.218)	-1.629 (0.103)	33.172**
5	Cubic $\ln(Y) = b_0 + b_1(t) + b_2 t^2 + b_3 t^3 + \varepsilon$	8.751** [0.045]	-0.019** [0.013]	-0.001* [0.001]	4.459E-5^{NS} [0.0001]	0.731	0.949 (0.240)	-1.629 (0.103)	25.433**
6	Compound $Y = b_0 b_1^{\,t} \varepsilon$	8.696** [0.028]	0.991** [0.002]			0.488	0.934 (0.105)	-4.085 (0.0001)	26.703**
7	Power $Y = b_0 t^{b_1} \varepsilon$	8.795** [0.039]	-0.092** [0.015]			0.584	0.934 (0.109)	-1.629 (0.103)	38.936**
8	Exponential $Y = b_0 e^{(b_1 t)}$	8.696** [0.028]	-0.009** [0.002]			0.488	0.934 (0.105)	-4.085 (0.0001)	26.703**

Value in ( ) - p value Value in [ ] – standard error NS- not significant

*- significant at 5% level of significance **- significant at 1% level of significance

Table 19. Fitted linear and non-linear models for production of cardamom in Tamil Nadu.

	Models	Regression coefficients				Goodness of fit			F-ratio
		b_0	b_1	b_2	b_3	Adj. R^2	Shapiro-wilk test	Run test	
1	Semi-log $\ln Y = b_0 + b_1(t) + \varepsilon$	6.406** [0.059]	0.019** [0.004]			0.488	0.935 (0.113)	-4.085 (0.0001)	26.786**
2	Double logarithmic $\ln(Y) = b_0 + b_1 \ln(t) + \varepsilon$	6.164** [0.070]	0.211** [0.028]			0.681	0.929 (0.083)	-1.629 (0.103)	58.656**
3	Inverse $\ln(Y) = b_0 + \frac{b_1}{t} + \varepsilon$	6.788** [0.034]	-0.809** [0.140]			0.545	0.953 (0.289)	-4.085 (0.0001)	33.325**
4	Quadratic $\ln(Y) = b_0 + b_1(t) + b_2t^2 + \varepsilon$	6.173** [0.073]	0.065** [0.012]	-0.002** [0.0001]		0.683	0.947 (0.218)	-1.629 (0.103)	30.025**
5	Cubic $\ln(Y) = b_0 + b_1(t) + b_2t^2 + b_3t^3 + \varepsilon$	6.043** [0.100]	0.114** [0.029]	-0.006* [0.002]	9.62E-5^{NS} [0.0001]	0.709	0.949 (0.240)	-1.629 (0.103)	22.963**
6	Compound $Y = b_0 b_1{}^t \varepsilon$	6.404** [0.058]	1.019** [0.004]			0.488	0.934 (0.105)	-4.085 (0.0001)	26.786**
7	Power $Y = b_0 t^{b_1} \varepsilon$	6.170** [0.065]	0.211** [0.028]			0.681	0.934 (0.109)	-1.629 (0.103)	58.656**
8	Exponential $Y = b_0 e^{(b_1 t)}$	6.404** [0.058]	0.019** [0.004]			0.488	0.934 (0.105)	-4.085 (0.0001)	26.786**

Value in ( ) - p value Value in [ ] – standard error NS- not significant

*- significant at 5% level of significance **- significant at 1% level of significance

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Table 20. Fitted linear and non-linear models for productivity of cardamom in Tamil Nadu.

	Models	Regression coefficients				Goodness of fit			F- ratio
		b_0	b_1	b_2	b_3	Adj. R^2	Shapiro-wilk test	Run test	
1	Semi-log $\ln Y = b_0 + b_1(t) + \varepsilon$	4.979** [0.062]	0.026** [0.004]			0.644	0.935 (0.113)	-4.085 (0.0001)	49.783**
2	Double logarithmic $\ln(Y) = b_0 + b_1 \ln(t) + \varepsilon$	4.667** [0.069]	0.287** [0.027]			0.807	0.929 (0.083)	-1.629 (0.103)	113.934**
3	Inverse $\ln(Y) = b_0 + \frac{b_1}{t} + \varepsilon$	5.508** [0.041]	-1.036** [0.172]			0.567	0.953 (0.289)	-4.085 (0.0001)	36.285**
4	Quadratic $\ln(Y) = b_0 + b_1(t) + b_2 t^2 + \varepsilon$	4.676** [0.061]	0.087** [0.010]	-0.002**		0.860	0.947 (0.218)	-1.629 (0.103)	83.824**
5	Cubic $\ln(Y) = b_0 + b_1(t) + b_2 t^2 + b_3 t^3 + \varepsilon$	4.647** [0.089]	0.098** [0.026]	-0.003^{NS} [0.002]	2.14E-5^{NS} [0.0001]	0.855	0.949 (0.240)	-1.629 (0.103)	54.184**
6	Compound $Y = b_0 b_1^t \varepsilon$	4.978** [0.059]	1.027** [0.004]			0.642	0.934 (0.105)	-4.085 (0.0001)	49.427**
7	Power $Y = b_0 t^{b_1} \varepsilon$	4.687** [0.060]	0.287** [0.027]			0.806	0.934 (0.109)	-1.629 (0.103)	113.066**
8	Exponential $Y = b_0 e^{(b_1 t)}$	4.978** [0.059]	0.026** [0.004]			0.642	0.934 (0.105)	-4.085 (0.0001)	49.427**

Value in ( ) - p value   Value in [ ] – standard error   NS- not significant

*- significant at 5% level of significance   **- significant at 1% level of significance

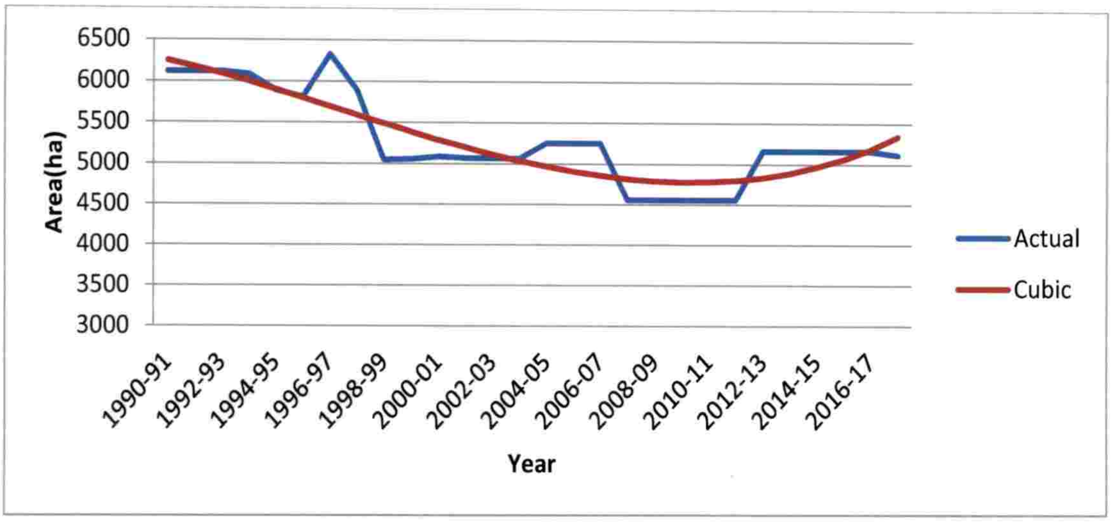

Figure 16. Actual and estimated trends in area of cardamom in Tamil Nadu.

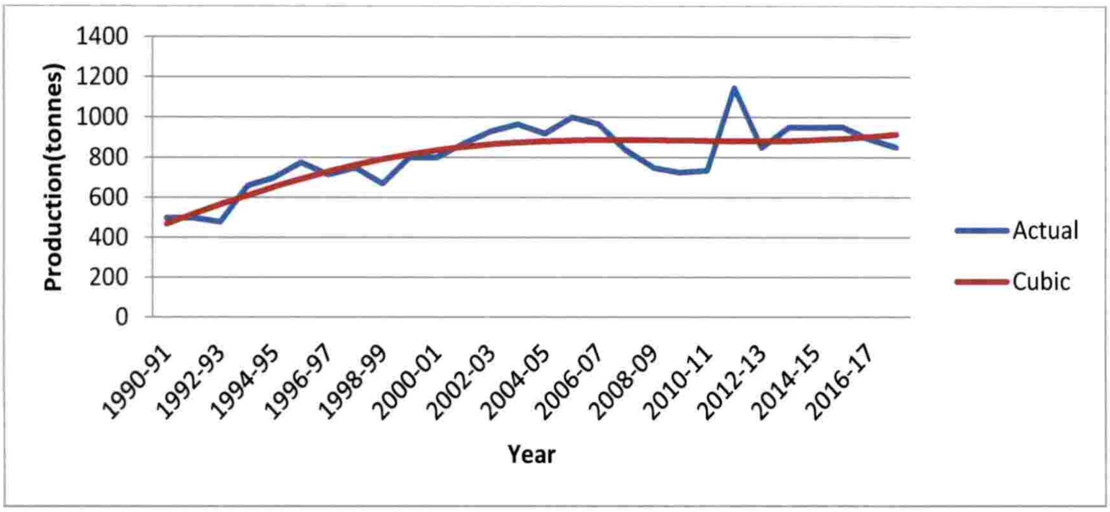

Figure 17. Actual and estimated trends in production of cardamom in Tamil Nadu.

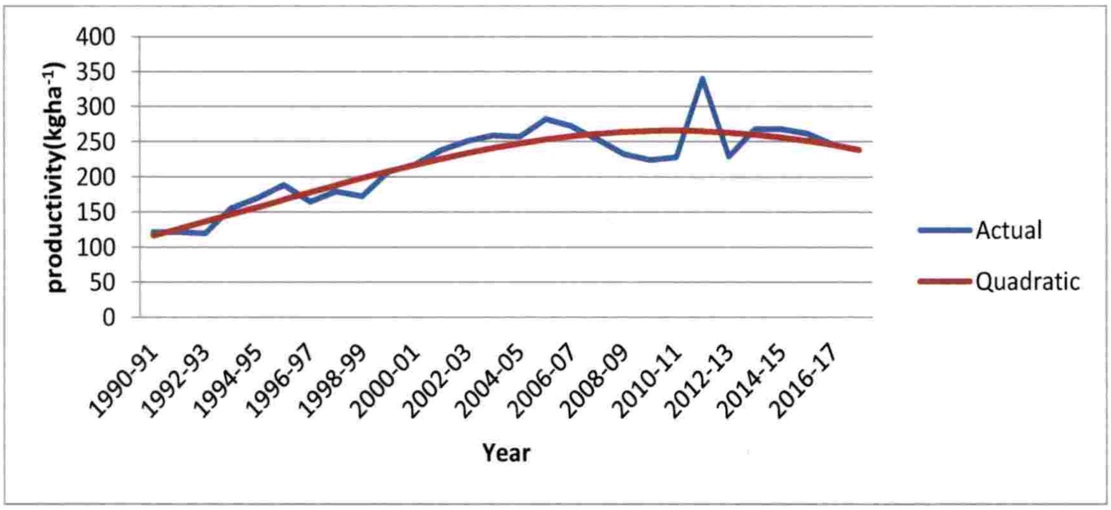

Figure 18. Actual and estimated trends in productivity of cardamom in Tamil Nadu.

4.2 COMPARATIVE ANALYSIS ON AREA, PRODUCTION AND PRODUCTIVITY OF COFFEE AND CARDAMOM AMONG SOUTH INDIAN STATES

The comparative performance in area, production and productivity in Kerala, Karnataka and Tamil Nadu was done based on the compound annual growth rates over time.

4.2.1 Coffee

In order to compare the performance in area, production and productivity of coffee in Kerala, Karnataka and Tamil Nadu during the period 1993-94 to 2017-18, compound annual growth rates were estimated and the results are presented in Table 21, 22 and 23 with discussions. The growth rates of Arabica coffee and Robusta coffee were also estimated separately.

4.2.1.1 Kerala

It is evident from Table 21 that Robusta coffee accounted for more than 90 percent to total area under coffee for the study period in Kerala. CAGR in area under Arabica coffee was negligible while area under Robusta coffee had shown an increasing trend (0.2%) during the period 1993-94 to 2017-18. Similar pattern of growth was noticed for production of Arabica coffee (-0.001%) and Robusta coffee (1.7%) in Kerala. However, productivity of Arabica coffee (0.8%) has shown insignificant positive CAGR, whereas Robusta coffee (1.6%) has shown significant positive CAGR.

The total area under coffee was 82348 ha in 1993-94 was increased to 85880 ha in 2017-18 with significant annual compound growth rate of 0.2 per cent. Total production also increased from 44360 tonnes to 65735 tonnes during the study period with significant CAGR of 1.6 per cent per annum. Total productivity (1.5%) has also shown significant increasing growth over time.

Table 21. Trends in area, production and productivity of coffee in Kerala along with CAGR.

Year	Area (ha)			Production (Tonnes)			Productivity (Kg ha^{-1})		
	Arabica	Robusta	Total	Arabica	Robusta	Total	Arabica	Robusta	Total
1993-94	4166	78182	82348	2510	41850	44360	510	535	539
1995-96	4166	78182	82348	1950	43200	45150	468	553	548
2000-01	4159	80576	84735	1750	68800	70550	421	854	833
2005-06	3992	80579	84571	1375	55450	56825	344	688	672
2010-11	3761	81170	84931	1625	64025	65650	446	795	780
2012-13	4175	81184	85359	2075	62125	64200	537	771	761
2015-16	4217	81284	85501	2200	67030	69230	557	830	817
2016-17	4228	81642	85870	2140	61125	63265	541	754	745
2017-18	4231	81649	85880	2160	63575	65735	546	785	774
CAGR (%)	0.1^{NS}	0.2**	0.2**	-0.001^{NS}	1.7**	1.6**	0.8^{NS}	1.6**	1.5**

**- significant at 1% level of significance NS- not significant
*- significant at 5% level of significance

4.2.1.2 Karnataka

It is evident from Table 22 that both varieties of coffee were cultivating in Karnataka. The area under Arabica coffee was 91867 ha in 1993-94 and it was increased to 108795 ha in 2017-18 with significant annual compound growth rate of 0.5 per cent. However, the area under Robusta coffee increased from 63458 ha in 1993-94 to 135990 ha in 2017-18. It indicates that growth in area (3.1%) under Robusta coffee was faster as compared to area under Arabica coffee in Karnataka.

Though, area under Arabica coffee has shown an increasing trend, growth of its production was negligible. But, there was more than two fold increase in production of Robusta coffee from 1993-94 to 2017-18 with a significant and positive CAGR of 3.9 per cent per annum.

The total productivity of coffee in Karnataka exhibited a significant and positive compound annual growth rate of 0.8 per cent. In case of Arabica coffee, , the growth rate of productivity was found to be negative (-0.4%) and not significant but Robusta coffee showed positive growth rate of 1.2 per cent which was significant at 1 per cent level of significance.

Table 22. Area, production and productivity of coffee in Karnataka along with CAGR

Year	Area (ha)			Production (Tonnes)			Productivity (Kg ha^{-1})		
	Arabica	Robusta	Total	Arabica	Robusta	Total	Arabica	Robusta	Total
1993-94	91867	63458	155325	79880	69490	149370	870	1095	962
1995-96	96379	72702	169081	74215	63250	137465	770	870	813
2000-01	110945	88605	199550	87850	123100	210950	792	1389	1057
2005-06	109614	112403	222017	76300	119975	196275	696	1067	884
2010-11	109173	118577	227750	74580	139200	213780	757	1269	1027
2012-13	109003	121330	230333	77425	152800	230225	772	1351	1079
2015-16	111225	124213	235438	78650	172870	251520	775	1480	1152
2016-17	108845	135940	244785	70510	151235	221745	707	1195	980
2017-18	108795	135990	244785	69025	153275	222300	692	1211	983
CAGR (%)	0.5**	3.1**	1.8**	-0.4^{NS}	3.9**	2.1**	-0.4^{NS}	1.2**	0.8**

**- significant at 1% level of significance NS- not significant
*- significant at 5% level of significance

4.2.1.3 Tamil Nadu

As compared to Kerala and Karnataka, per cent share of area under Arabica coffee was more in Tamil Nadu (Table 23). In Tamil Nadu total area under coffee exhibited a positive growth rate and it was found significant (0.3%).

Table 23. Area, production and productivity of coffee in Tamil Nadu along with CAGR.

Year	Area (ha)			Production (Tonnes)			Productivity (Kg ha^{-1})		
	Arabica	Robusta	Total	Arabica	Robusta	Total	Arabica	Robusta	Total
1995-96	27270	5508	32778	11800	3560	15360	433	646	469
2000-01	25018	5663	30681	11800	4650	16450	472	821	536
2005-06	25108	5556	30664	14375	4450	18825	573	801	614
2010-11	25739	5605	31344	12150	4500	16650	495	803	552
2012-13	25939	5605	31544	12800	4570	17370	523	826	579
2015-16	29062	5870	34932	12810	4485	17295	478	783	532
2016-17	29513	6094	35607	11850	4485	16335	427	772	487
2017-18	29513	6094	35607	13400	4040	17440	482	695	519
CAGR (%)	0.3*	0.2**	0.3*	-0.001^{NS}	1.3**	0.2^{NS}	-0.001^{NS}	1.2**	0.3^{NS}

**- significant at 1% level of significance NS- not significant
*- significant at 5% level of significance

The CAGR of area under Arabica coffee (0.3%) and Robusta coffee (0.2%) were positive and significant. Even if area under Arabica coffee has increased, the growth rate of its production was negligible while a significant and positive growth rate was noticed for Robusta coffee (1.3%) in Tamil Nadu. Further, a positive and significant CAGR in productivity of Robusta coffee (1.2%) was noticed in Tamil Nadu.

4.2.2 Cardamom

In order to compare the performance in area, production and productivity of cardamom in Kerala, Karnataka and Tamil Nadu during the period 1990-91 to 2017-18, compound annual growth rates were estimated and the results are presented in Table 24, 25 and 26 below with discussions.

4.2.2.1 Kerala

It is evident from Table 24 that the area under cardamom in Kerala was 43826 ha in 1990-91and it declined to 39080 ha in 2017-18. The estimated CAGR of area (-0.4%) under cardamom in Kerala was negative and significant.

Table 24. The area, production and productivity of cardamom in Kerala along with CAGR.

Year	Area (ha)	Production (Tonnes)	Productivity (Kg ha^{-1})
1990-91	43826	3450	86
1995-96	44248	5380	165
2000-01	41288	7580	247
2005-06	41367	9765	318
2010-11	41242	7935	272
2012-13	39660	11350	383
2015-16	39680	21503	680
2016-17	39080	15650	502
2017-18	39080	18350	581
CAGR (%)	-0.4**	6.0**	6.5**

**- significant at 1% level of significance
*- significant at 5% level of significance

However, the production has increased from 3450 tonnes in 1990-91 to 18350 tonnes in 2017-18 with high positive growth rate of 6 per cent per annum. Productivity of cardamom has shown 7 fold increases from 1990-91 to 2017-18. The estimated CAGR of productivity (6.5%) was very high which indicates that the adoption of high yielding varieties and better management practices by the growers may be contributed to enhance the productivity.

4.2.2.2 Karnataka

Table 25 showed that the area under cardamom in Karnataka decreased from 31605 ha to 25135 ha; while the production has shown an increasing trend i.e. 800 tonnes in 1990-91 to 1500 tonnes in 2017-18. But productivity of cardamom in Karnataka was very less as compared to Kerala and it fluctuated

Table 25. The area, production and productivity of cardamom in Karnataka along with CAGR.

Year	Area (ha)	Production (Tonnes)	Productivity (Kg ha^{-1})
1990-91	31605	800	43
1995-96	33743	1745	69
2000-01	25947	2100	109
2005-06	27173	1775	85
2010-11	25210	1710	95
2012-13	25050	1800	104
2015-16	25242	1437	80
2016-17	25117	1449	81
2017-18	25135	1450	82
CAGR (%)	-1.0**	0.4^{NS}	1.5**

**- significant at 1% level of significance NS- not significant
*- significant at 5% level of significance

over the years . The estimated CAGR was negative and significant in case of area (-1%), negligible for production and positive and significant for productivity (1.5%) of cardamom in Karnataka.

4.2.2.3 Tamil Nadu

Table 26 showed that the area under cardamom in Tamil Nadu was declined from 6123 ha in 1990-91 to 5115 ha in 2017-18 with a negative and significant annual compound growth rate of -0.9 per cent. But the production has shown a fluctuating trend during the period 1990-91 to 2017-18 with a positive and significant growth rate of 1.9 per cent per annum. Productivity was increased from 122 kg ha^{-1} in 1990-91 to 238 kg ha^{-1} in 2017-18 with a positive and significant growth rate of 2.6 per cent per annum.

Table 26. The area, production and productivity of cardamom in Tamil Nadu along with CAGR.

Year	Area (ha)	Production (Tonnes)	Productivity (Kg ha^{-1})
1990-91	6123	500	122
1995-96	5811	775	189
2000-01	5085	800	217
2005-06	5255	1000	282
2010-11	4560	735	228
2012-13	5160	850	229
2015-16	5160	952	262
2016-17	5160	891	246
2017-18	5115	850	238
CAGR (%)	-0.9**	1.9**	2.6**

**- significant at 1% level of significance
*- significant at 5% level of significance

It is evident from Figure 19 that, the CAGR in area, production and productivity of Robusta coffee was significant and positive in all the three states and it was highest in Karnataka followed by Kerala and Tamil Nadu. Arabica coffee has shown significant and positive CAGR in area only in Karnataka and Tamil Nadu whereas, production and productivity was negligible in all the three states. Total area, production and productivity of coffee showed a significant and positive growth in Karnataka and Kerala while in Tamil Nadu only area showed significant and positive growth.

In case of cardamom, it is evident from Figure 20 that CAGR in area was significant and negative in all the three states and it was highest in Karnataka followed by Tamil Nadu and Kerala. Production and productivity shown significant and positive CAGR in in all the three states and it was highest in Kerala followed by Tamil Nadu and Karnataka. Moreover, productivity of cardamom in Kerala was two times more than productivity in Tamil Nadu and seven times larger than productivity in Karnataka.

Dastagiri (2017) studied the trends and growth rates in exports and price of Indian coffee and showed that, growth rate in export and price of Indian coffee was significant and positive.

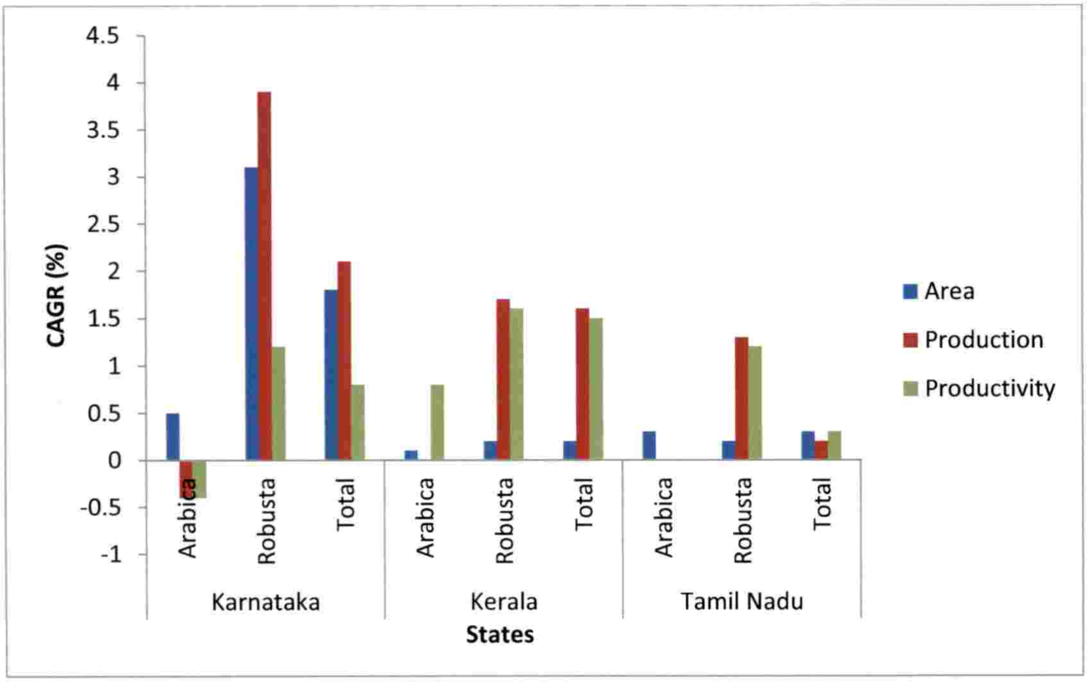

Figure 19. CAGR (%) in area, production and productivity of coffee in Kerala, Karnataka and Tamil Nadu.

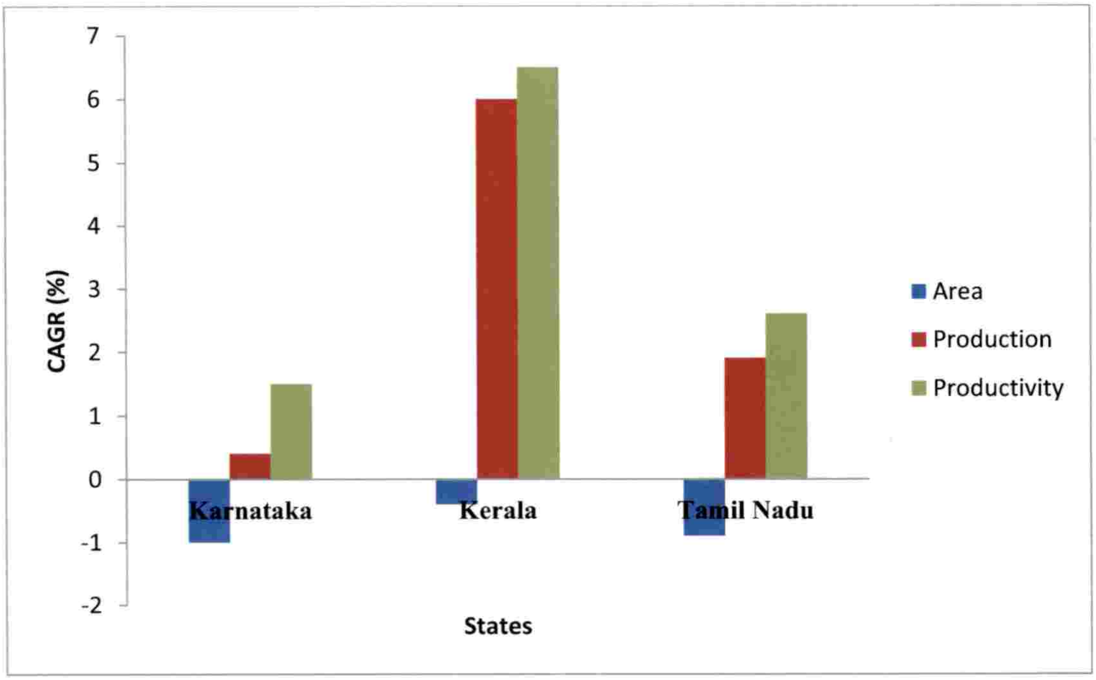

Figure 20. CAGR (%) in area, production and productivity of cardamom in Kerala, Karnataka and Tamil Nadu.

4.3 COINTEGRATION BETWEEN MARKET PRICES

Cointegration technique is used to estimate long run equilibrium relationship between prices of a commodity at different markets. The integration between the prices of coffee in two markets was tested using the cointegration technique for two grades of clean coffee namely Arabica Plantation A and Robusta Cherry AB. The selected two markets of coffee were Bengaluru and Chennai. In case of coffee wholesale market prices of two grades of coffee namely Arabica Plantation A and Robusta Cherry AB are available at Bengaluru and Chennai markets. Also, integration between the cardamom prices of Kerala and Karnataka were tested by using auction price series. However, for cardamom, auction price of cardamom in Kerala and Karnataka are available. The co-movement of price of coffee and cardamom at different markets was studied using Engle-Granger Cointegration technique.

This analysis was carried out in two steps. The first step involves the verification of stationarity of the individual price series using Augmented Dickey-Fuller (ADF) test. The second step includes the verification of long run synchronous movements of prices of coffee and cardamom in two specified markets.

4.3.1 Market integration of price of coffee in Bengaluru and Chennai market

To have some basic idea about the prices, descriptive statistics of both grades of coffee in Bengaluru and Chennai markets were calculated and it is presented in Table 27.

Table 27. Descriptive statistics of two grades of coffee in Bengaluru and Chennai markets.

Statistics	Arabica Plantation A		Robusta Cherry AB	
	Bengaluru	Chennai	Bengaluru	Chennai
Mean (Rs kg^{-1})	160.14	169.85	92.99	101.37
Std. deviation (Rs kg^{-1})	80.80	86.60	43.64	47.23
Skewness	0.58	0.65	0.37	0.47
Kurtosis	-0.88	-0.91	-1.05	-0.10
C.V (%)	50.46	50.99	46.93	46.59

Stationarity of monthly wholesale price data of two grades of coffee in Bengaluru and Chennai market is tested using Augmented Dickey- Fuller (ADF) test by including drift in the equation of the prices. The equation used is

$$\Delta Y_t = \alpha + \beta Y_{t-1} + \sum_{i=1}^{p} \delta_i \Delta Y_{t-i} + \varepsilon_t$$

where Y_t – is the price of coffee or cardamom in one of the markets.

Test for stationarity is same as that of testing for unit roots and the results of ADF test are presented in Table 28. The null hypothesis H_0: $\beta = 0$ VS H_1: $\beta < 0$ is accepted, it suggests the presence of unit root, and otherwise the series is stationary. It is evident from the Table 28 that price of Arabica Plantation A and Robusta Cherry AB in Bengaluru and Chennai markets were not stationary as the p-value is much larger than 5 per cent and 1 per cent level of significance. However, the estimated p-values of the test statistic was even smaller than 0.01

Table 28. Results of ADF tests for stationarity of prices for Arabica Plantation A and Robusta Cherry AB grades of coffee in Bengaluru and Chennai market.

Price series	Order of Integration	Series	Coefficient " β "	Dickey Fuller value	p-value
Arabica Plantation A (Bengaluru)	1	Level	-0.007	-1.018	0.748
		1st difference	-0.826	-8.633	<0.01
Arabica Plantation A (Chennai)	1	Level	-0.007	-0.797	0.819
		1st difference	-1.065	-9.424	<0.01
Robusta Cherry AB (Bengaluru)	1	Level	-0.007	-1.011	0.751
		1st difference	-0.775	-13.111	<0.01
Robusta Cherry AB (Chennai)	1	Level	-0.016	-0.715	0.841
		1st difference	-2.777	-11.164	<0.01

The model used is $\Delta Y_t = \alpha + \beta Y_{t-1} + \sum_{i=1}^{p} \delta_i \Delta Y_{t-i} + \varepsilon_t$

for differenced price, implies that Arabica Plantation A and Robusta Cherry AB grades of coffee in Bengaluru and Chennai markets were stationary and hence, concluded that price of Arabica Plantation A and Robusta Cherry AB were integrated of order one I(1). The line graphs of original and differenced price of both grades of coffee were presented in Figure21-28. It is also evident from the graph that each price series was I(1) and it allowed to proceed with Engle-Granger Cointegration technique to test for cointegration.

Then cointegration was examined between price of Arabica Plantation A as well as for price of Robusta Cherry AB in Bengaluru and Chennai markets. To test for cointegration between prices in different markets, Engle-Granger test was used. Since the price of both grades of coffee in Bengaluru and Chennai markets were found to be integrated of same order I(1), a regression of the form $Y_t = \alpha_0 + \alpha_1 X_t + \varepsilon_t$ was estimated by taking price at one market as dependent (Y_t) and price at second market as independent variable (X_t) by using ordinary least square method. The residual series of regression ε_t is tested for its stationarity using Augmented Dickey-Fuller test. The results of cointegrating regression and ADF test on residuals are presented in Table 29 and Table 30.

Table-29. Cointegrating regression for Arabica Plantation A and Robusta Cherry AB

Dependent variable (Y_t)	Constant	X_t	Coefficient of X_t	S.E	t-ratio	Adj. R^2	AIC
Arabica Plantation A at Chennai	0.215**	Arabica Plantation A at Bengaluru	0.968**	0.010	94.56	0.970	−555.07
Robusta Cherry AB at Bengaluru	0.317**	Robusta Cherry AB at Chennai	0.910**	0.018	48.00	0.893	−201.47

The coefficients are estimated using the relation $Y_t = \alpha_0 + \alpha_1 X_t + \varepsilon_t$

The adjusted R^2 of cointegrating regressions were about 97 per cent for Arabica Plantation A and 89 per cent for Robusta Cherry AB confirms the goodness of fit of estimates of regression and the results of ADF test on residuals ε_t of cointegrating regressions confirmed cointegration of price of two grades of coffee in Bengaluru and Chennai markets. Further, it can be observed from the

Figure 29 and Figure 30 that price at Bengaluru and Chennai market moving together for Arabica Plantation A and Robusta Cherry AB.

Table 30. Results of test of integration of markets

Markets	Order of Integration	Coefficient “β”	Dickey Fuller Value	p-value
Bengaluru and Chennai (Arabica Plantation A)	0	-0.346	-6.138	<0.01
Bengaluru and Chennai (Robusta Cherry AB)	0	-0.627	-7.253	<0.01

These results were in harmony with research work of Yashavanth (2010), who conducted the study on co-movement of coffee price in Karnataka and world market. The study reported that the price in Karnataka and World coffee market were co-integrated for both the varieties of coffee (Arabica coffee and Robusta coffee). In another study by Naveena *et al.* (2016) reported that, there was a long run association between Indian Arabica coffee price and world Arabica coffee price as well as Indian Robusta coffee price and world Robusta coffee price.

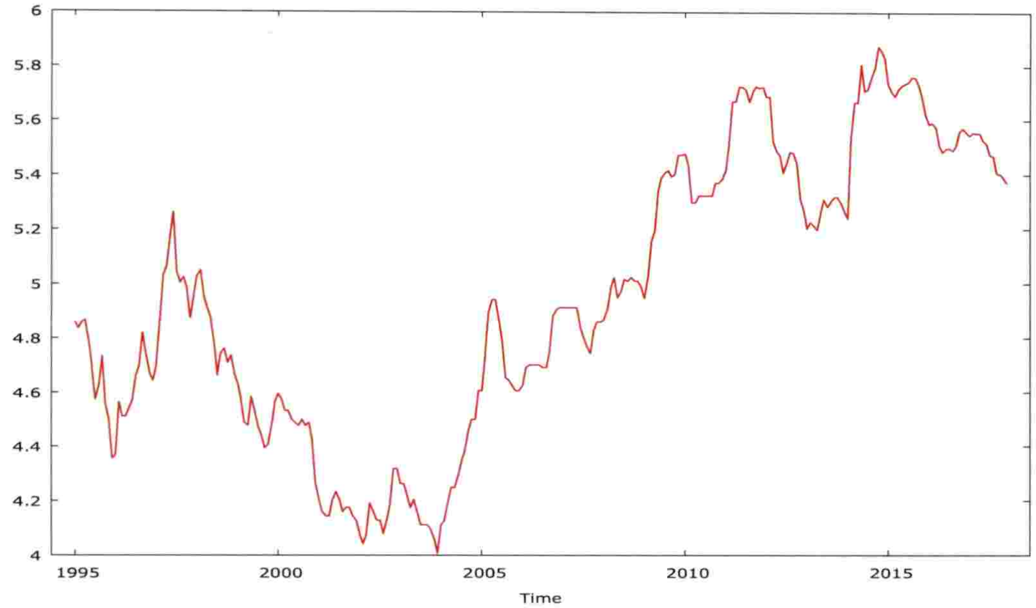

Figure 21. Trends in price of Arabica Plantation A in Bengaluru market.

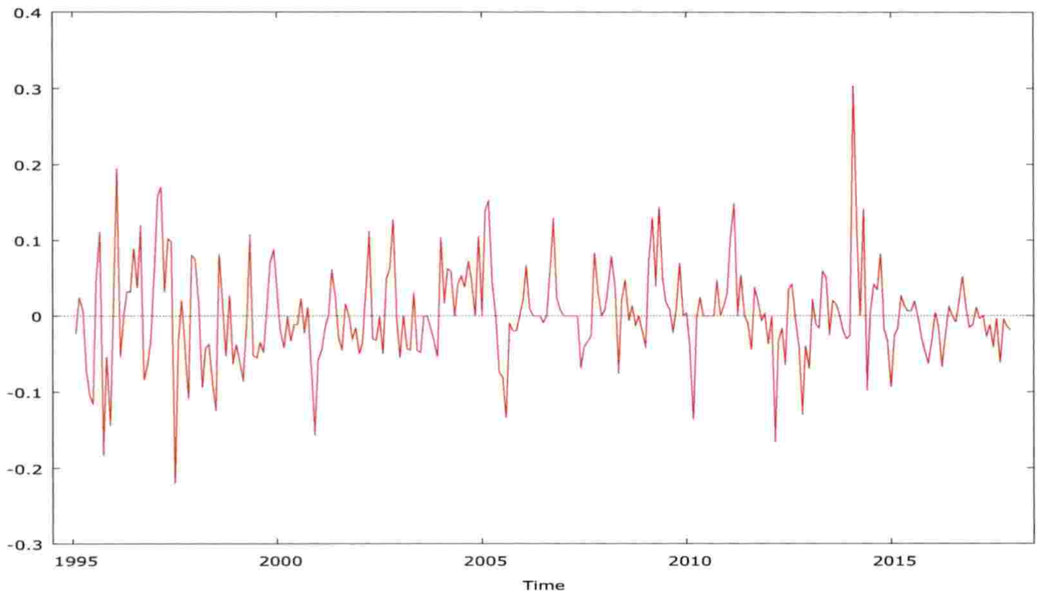

Figure 22. Trends in change in price of Arabica Plantation A in Bengaluru market (differenced series)

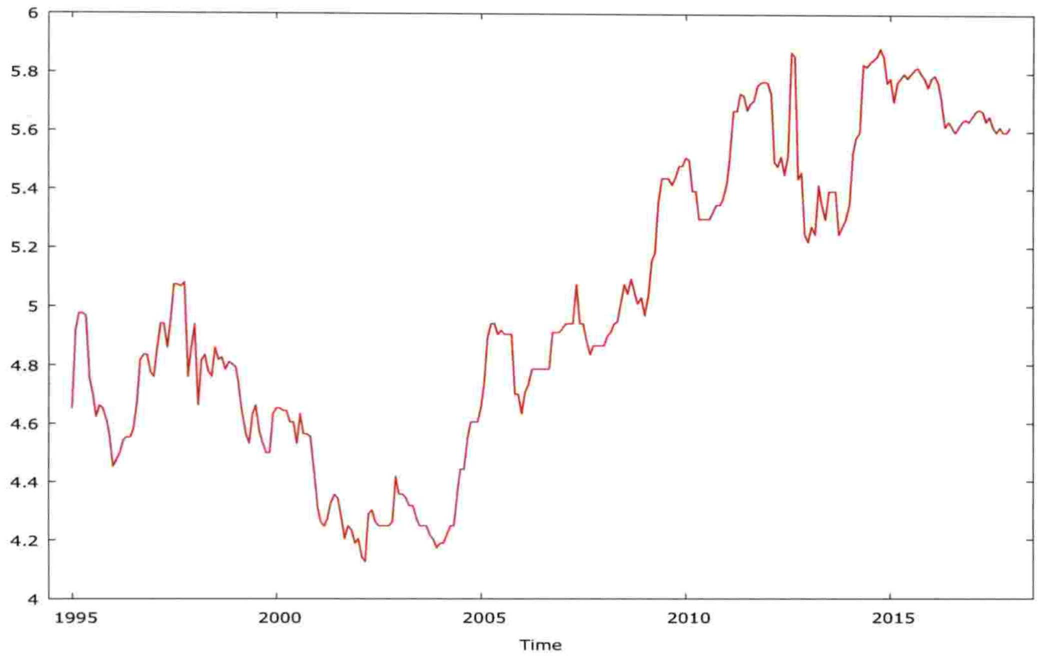

Figure 23. Trends in price of Arabica Plantation A in Chennai market

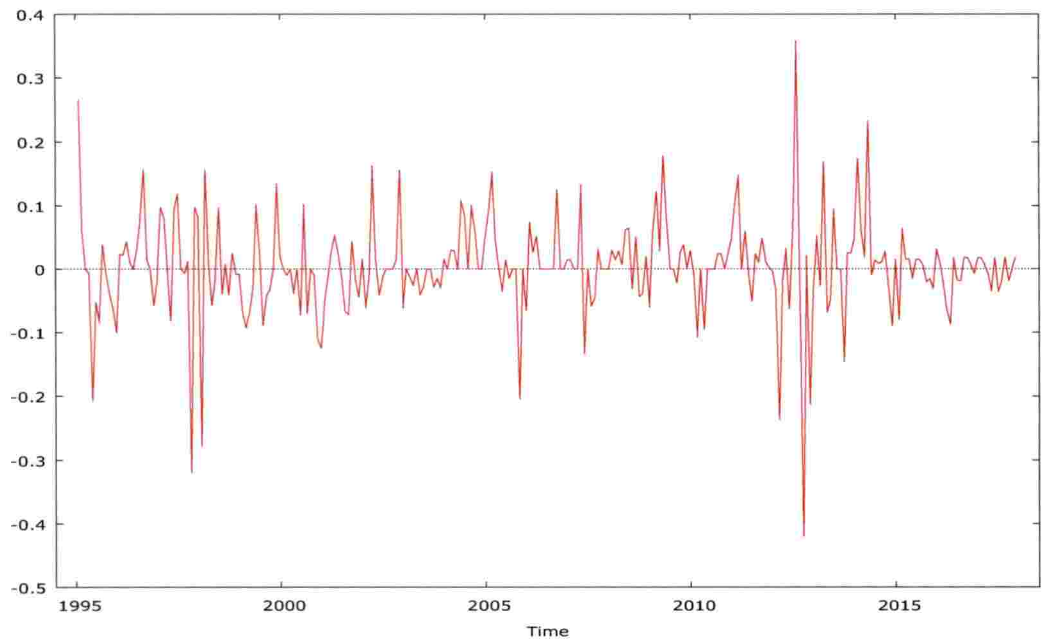

Figure 24. Trends in change in price of Arabica Plantation A in Chennai market (differenced series)

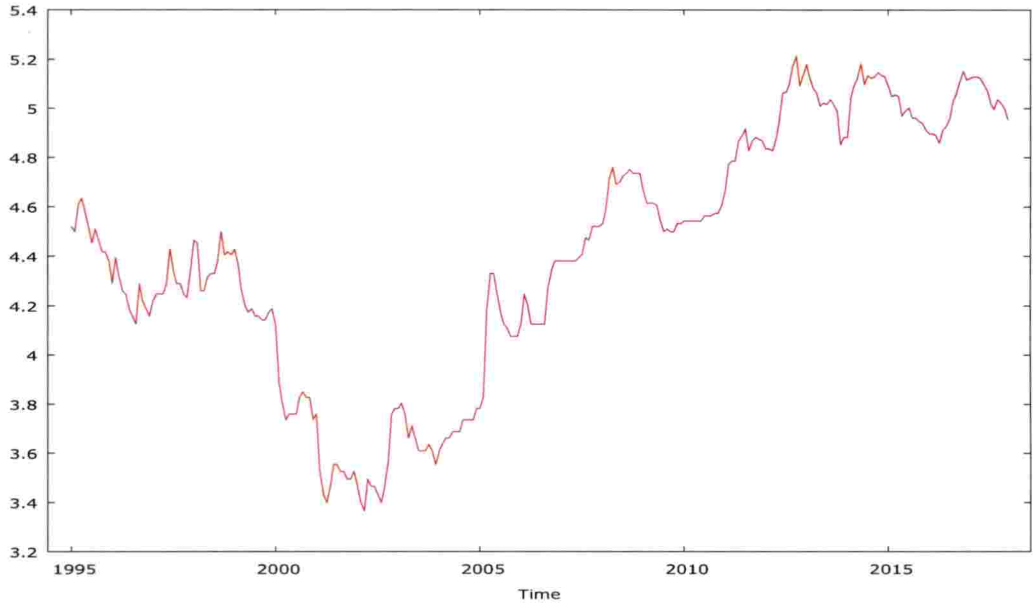

Figure 25. Trends in price of Robusta Cherry AB in Bengaluru market.

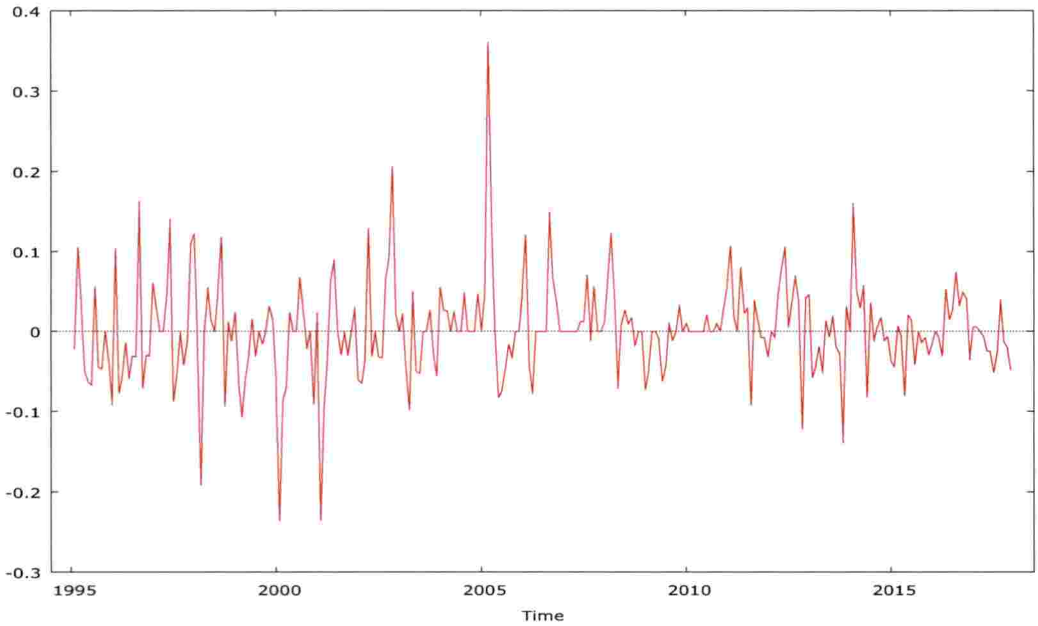

Figure 26. Trends in change in price of Robusta Cherry AB in Bengaluru market (differenced series)

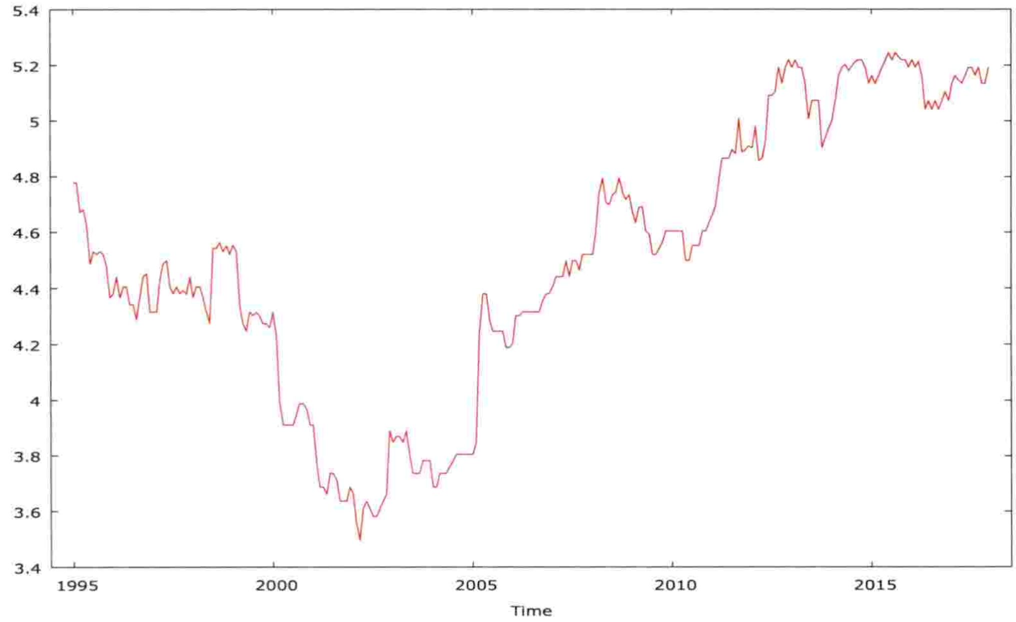

Figure 27. Trends in price of Robusta Cherry AB in Chennai market

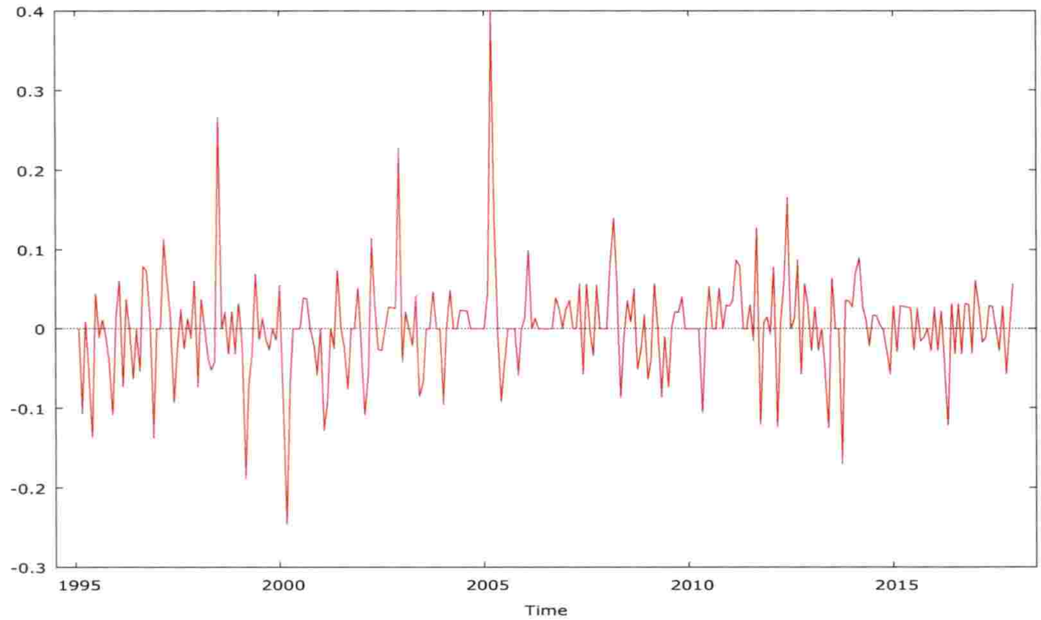

Figure 28. Trends in change in price of Robusta Cherry AB in Bengaluru market (differenced series).

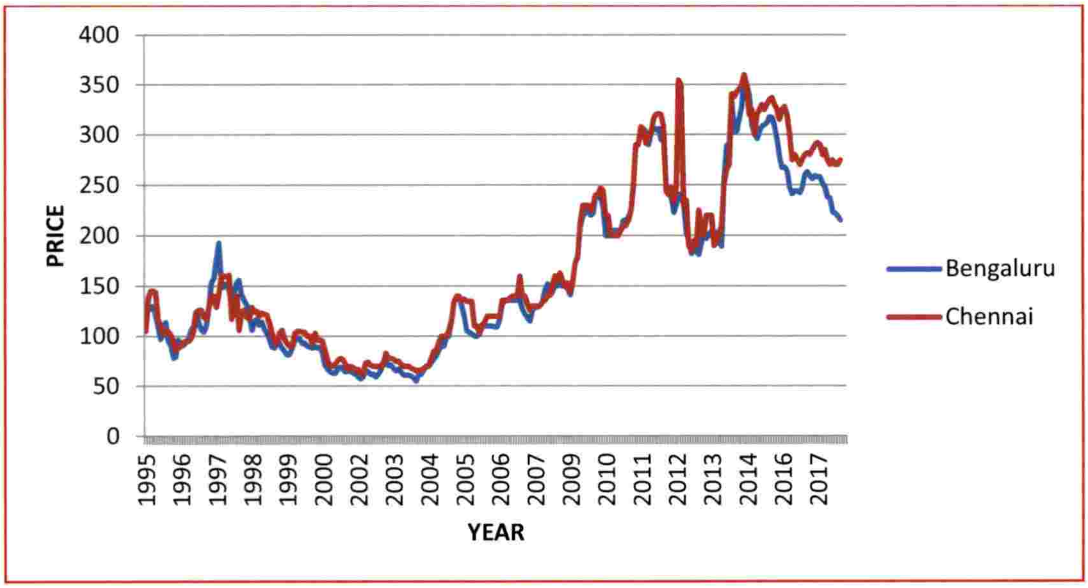

Figure 29. Trends in price of Arabica Plantation A in Bengaluru and Chennai market.

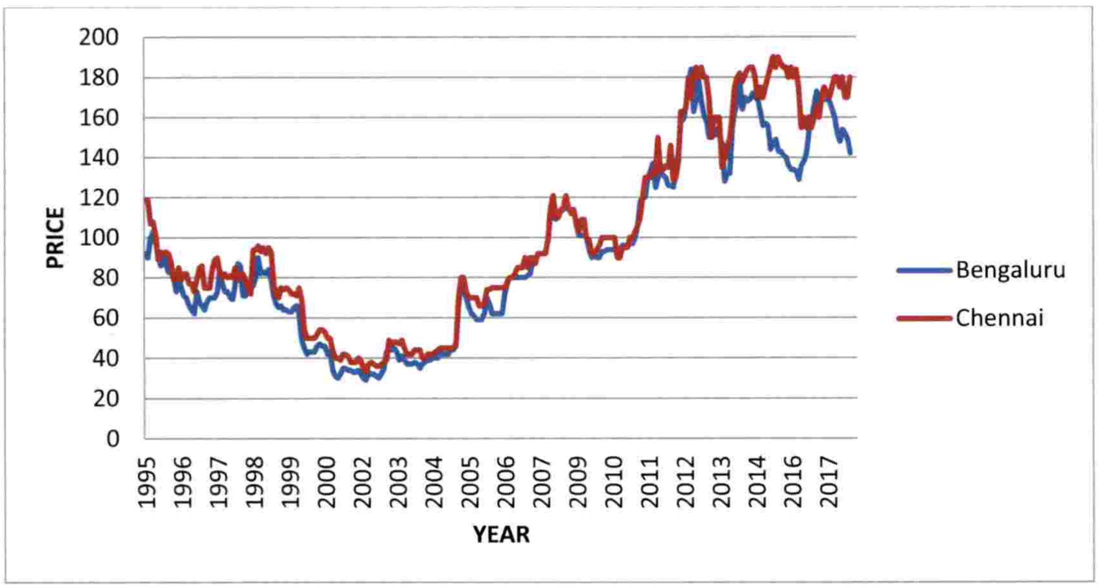

Figure 30. Trends in price of Robusta Cherry AB in Bengaluru and Chennai market.

4.3.2 Market integration of price of cardamom in Kerala and Karnataka markets

To have some basic idea about the prices, descriptive statistics of price of cardamom in Kerala and Karnataka markets were calculated and is presented in Table 31. It is evident from the table that auction price of cardamom was high in Kerala than Karnataka.

Table 31. Descriptive statistics of auction prices of cardamom in Kerala and Karnataka

Statistics	Kerala	Karnataka
Mean (Rs kg^{-1})	538.02	426.56
Std. deviation (Rs kg^{-1})	270.11	192.56
Skewness	0.95	1.08
Kurtosis	0.80	1.30
C.V	50.21	45.14

Stationarity of monthly auction price data of cardamom in Kerala and Karnataka market is tested using Augmented Dickey- Fuller (ADF) test by including drift in the equation of the prices. Test for stationarity is same as that of testing for unit roots and the results of ADF test are presented in Table 32. The null hypothesis H_0: $\beta = 0$ VS H_1: $\beta < 0$ is accepted, suggests the presence of unit root, otherwise the series is stationary. It is evident from the Table 32 that price of cardamom in Kerala and Karnataka markets were not stationary as the p-value was much larger than the probability 0.05 and 0.01. However, the estimated p-values of the test statistic was even smaller than 0.01 for differenced price, implies that cardamom price in Kerala and Karnataka markets were stationary and hence concluded that price of cardamom in both markets were integrated of order one I(1). The line graphs of original and differenced price of cardamom were presented in Figure31-34. These results were also confirmed from the graph and hence it is allowed to proceed with Engle-Granger Cointegration technique to test for cointegration.

Table 32. Results of stationarity of auction price of cardamom in Kerala and Karnataka market.

Price series	Order of Integration	Series	Coefficient " β "	Dickey Fuller value	p-value
Kerala	1	Level	-0.025	-2.227	0.196
		1st difference	-0.838	-7.897	<0.01
Karnataka	1	Level	-0.043	-2.311	0.168
		1st difference	-1.285	24.298	<0.01

The model used is $\Delta Y_t = \alpha + \beta Y_{t-1} + \sum_{i=1}^{p} \delta_i \Delta Y_{t-i} + \varepsilon_t$

The co-movement of auction price of cardamom in Kerala and Karnataka was analysed using Engle-Granger Cointegration technique. Since the price of cardamom in Kerala and Karnataka was found to be integrated of same order I(1), the cointegrating regression of the form $Y_t = \alpha_0 + \alpha_1 X_t + \varepsilon_t$ is formed and estimated, where Y_t denote auction price in Kerala market and X_t represent auction price in Karnataka market. The residual series of regression ε_t is tested for its stationarity using Augmented Dickey-Fuller test. The results of cointegrating regression and ADF test on residuals are presented in Table 33 and 34.

Table 33. Results of cointegrating regression of cardamom.

	Coefficient	Std. error	t-ratio	p-value
Constant	−0.133	0.144	−0.920	0.358
Karnataka	1.056 **	0.024	43.80	<0.01
Dependent variable(Y_t)	Kerala			
R-squared	0.851			
Adjusted R-squared	0.851			
Akaike criterion	−144.624			
Schwarz criterion	−136.990			

The coefficients are estimated using the relation $Y_t = \alpha_0 + \alpha_1 X_t + \varepsilon_t$

Table 34. Results of test for integration of markets.

Markets	Order of Integration	Coefficient " β "	Dickey Fuller value	p-value
Kerala and Karnataka	0	-0.210	-4.925	<0.01

The adjusted R^2 of cointegrating regression was about 85 per cent which confirms the goodness of fit of regression analysis. The results of ADF test on residuals (ε_t) of cointegrating regression confirmed the cointegration of auction price of cardamom in Kerala and Karnataka market. Similar conclusion was noticed from Figure 35 that auction price in Kerala and Karnataka markets move together. This result tends to suggest that any change in price in one market immediately be transmitted to price in another market.

Nirmala *et al.* (2015), who studied the cointegration between the futures price and spot price of cardamom, showed that cardamom futures and spot prices were cointegrated and there exists a long-term relationship between the futures and spot price series.

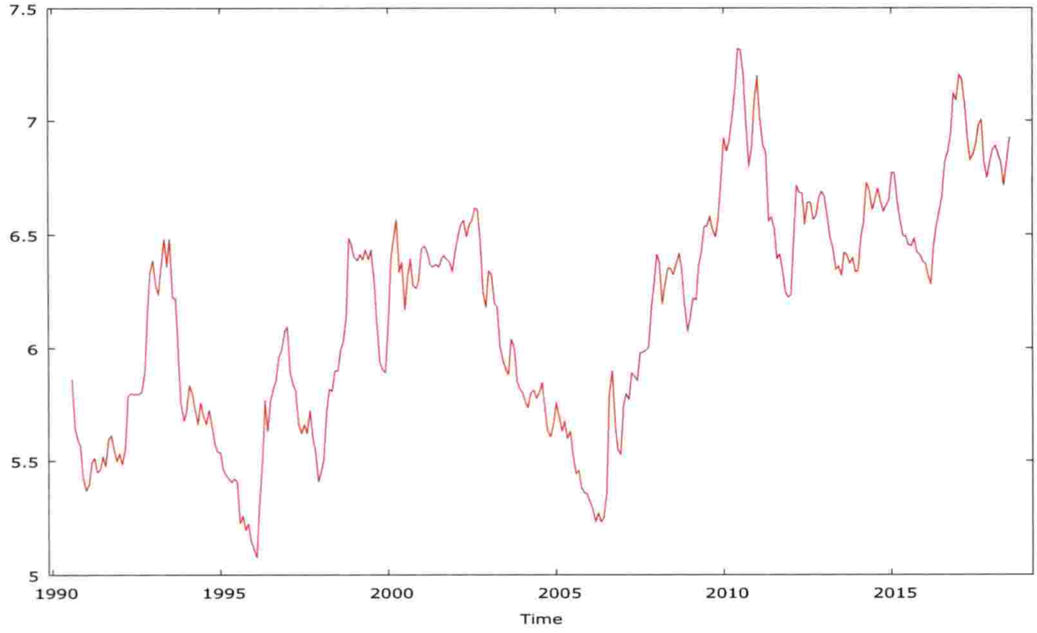

Figure 31. Trends in price of cardamom in Kerala market.

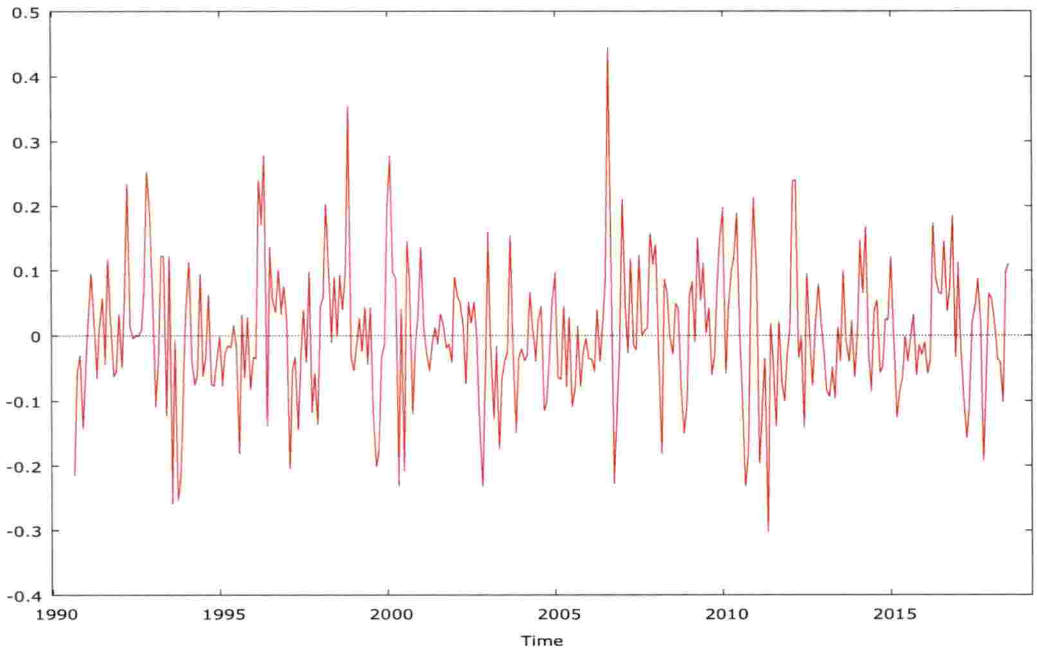

Figure 32. Trends in change in price of cardamom in Kerala market (differenced series).

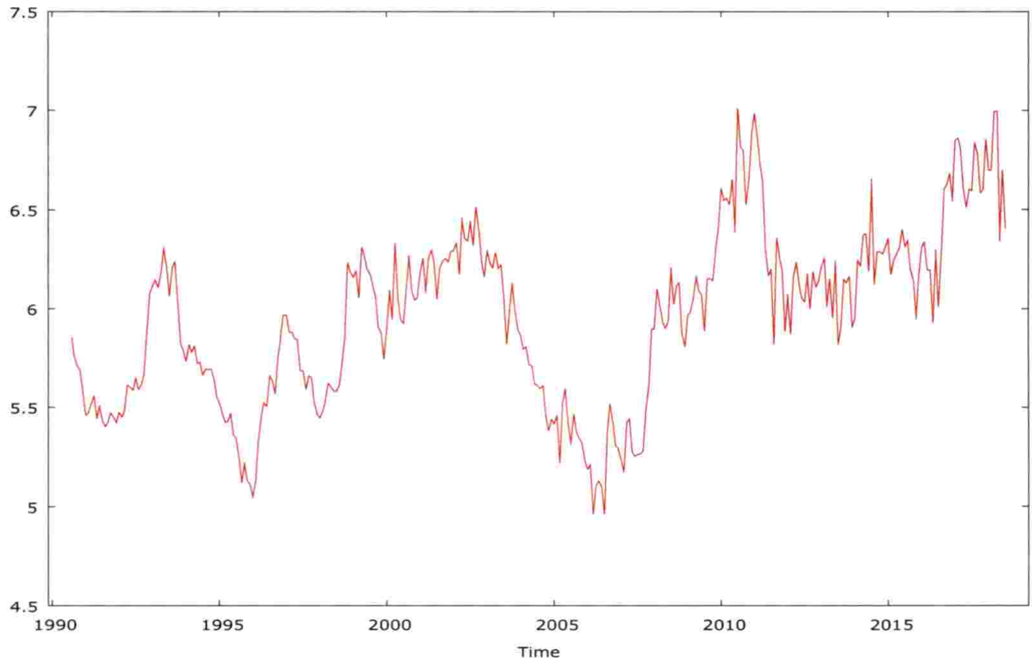

Figure 33. Trends in price of cardamom in Karnataka market.

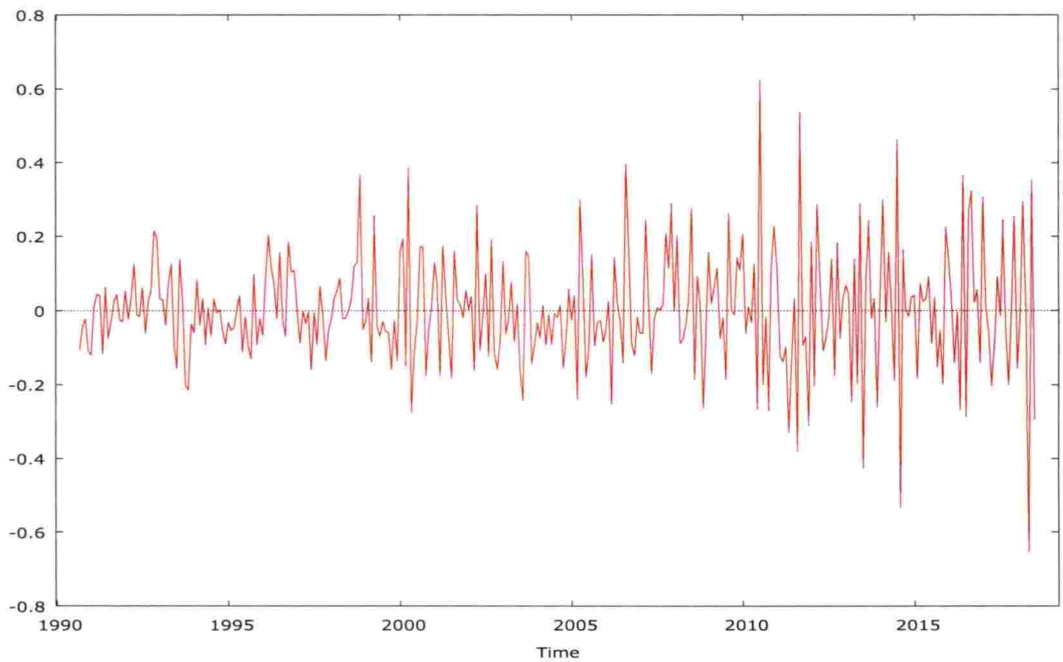

Figure 34. Trends in change in price of cardamom in Karnataka market (differenced series).

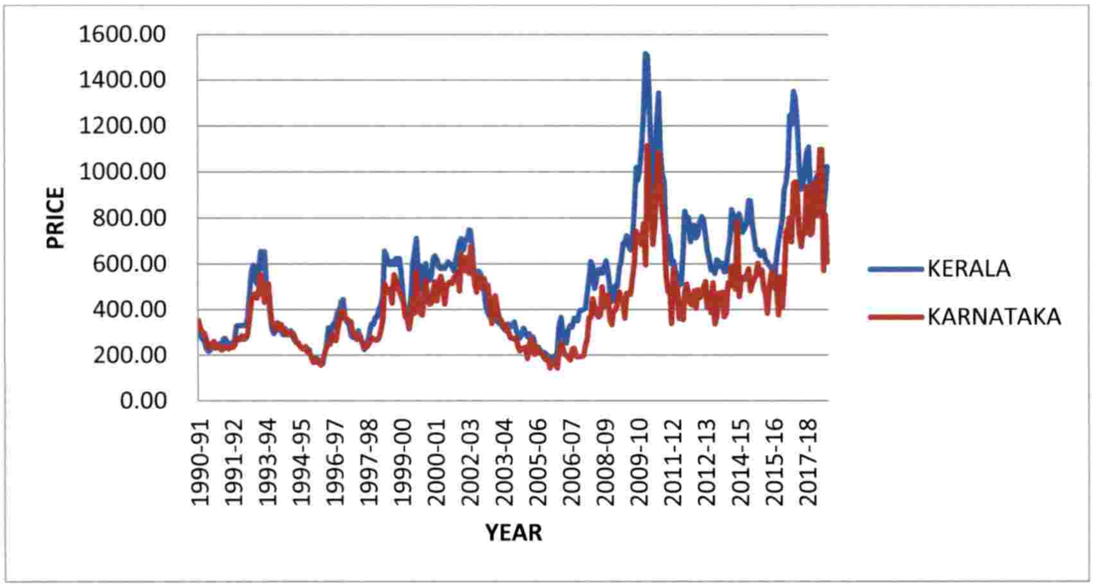

Figure 35. Trends in price of cardamom in Kerala and Karnataka market.

4.4 PRICE VOLATILITY

The price volatility is the degree of variation of price over time. In order to measure the presence of volatility in coffee and cardamom prices, ARCH-GARCH model was carried out for the price in selected markets of coffee and cardamom. In case of coffee, auction price of different grades of coffee in Bengaluru market was selected for volatility analysis. And in case of cardamom volatility was analysed using auction price in Karnataka and Kerala.

4.4.1 Volatility of coffee prices

The comovement of price of coffee in Bengaluru (Karnataka) and Chennai (Tamil Nadu) was studied based on wholesale price of two grades of coffee namely Arabica Plantation A an Robusta Cherry AB. However, the variability in price of different grades of coffee was analysed using the auction price of three major grades of coffee namely Arabica plantation A, Arabica cherry AB and Robusta parchment AB.

To have some basic idea about the prices, descriptive statistics of all the three grades of coffee were calculated and it is presented in Table 35. The average price of Arabica plantation A, Arabica cherry AB, and Robusta parchment AB grades of coffee were 7432.2, 5581.726 and 5093.873 Rs 50 kg^{-1} respectively indicated that price of Arabica Plantation A was much higher than other two grades.

Table 35. Descriptive statistics of three grades of coffee

Statistics	Arabica plantation A	Arabica cherry AB	Robusta parchment AB
Mean (Rs 50 kg^{-1})	7434.2	5581.726	5093.873
Std. deviation (Rs50kg^{-1})	3795.259	2752.035	2546.342
Skewness	-1.098	-0.997	-1.093
Kurtosis	0.418	0.327	0.269
C.V (%)	51.051	49.304	49.988

Standard deviation was highest for Arabica plantation A (3795.259) as compared to Arabica cherry AB (2752.035) and Robusta parchment AB (2546.342). Coefficient of variation was very high for all the three grades of coffee i.e., 51.05 per cent for Arabica plantation A, 49.304 per cent for Arabica cherry AB 49.988 percent for Robusta parchment AB, which indicating the high variability in price of all three grades of coffee.

In time series analysis, assumption of stationary of the data sets is the most important. So, stationarity of price of all the three grades of coffee namely Arabica plantation " A", Arabica cherry AB, and Robusta parchment AB were tested using Augmented Dickey Fuller (ADF) test. The results of ADF test in Table 36 showed that the test failed to reject the null hypothesis of "The price series are not stationary", which indicates that all the three price series were nonstationary in level form. But, the ADF test rejected the null hypothesis for all the differenced price series and this suggests that series were stationary at their first differences.

Table 36. Stationarity test for Auction Prices of Major Grades of Clean Coffee (Rs50 kg^{-1})

Major Grades of Clean Coffee	Series	ADF test	p-value
Arabica plantation A	Level	-1.035	0.742
	1st difference	-21.280	<0.01
Arabica cherry AB	Level	-1.029	0.745
	1st difference	-18.697	<0.01
Robusta parchment AB	Level	-1.139	0.702
	1st difference	-17.156	<0.01

In general, we study the pattern of change in a data by using standard deviation or coefficient of variation or some instability measures. However, when we discuss about time series data, the assumption of constant variance for a long period is violated. If this assumption is violated we go for ARCH-GARCH modeling. Before fitting the GARCH model, it is necessary to check the presence of ARCH effect. ARCH-LM test is done to check the presence of volatility. Mean equation is fitted and the residuals were used to check for ARCH effect by using Lagrange-Multiplier (LM) test. In order to apply ARCH-LM test $r_t = \ln(Y_t / Y_{t-1})$, t=1, 2, … generated first and a regression of r_t on its own lag terms was estimated. This equation is generally known as mean equation. The Lagrange-Multiplier (LM) test applied to the residuals of mean equation and the results along with *p*-values are presented in Table 37.

Table 37. Results of Lagrange-Multiplier test on coffee

Series	LM test statistic	p-value
Arabica plantation A	45.473**	<0.01
Arabica cherry AB	10.773*	<0.05
Robusta parchment AB	8.682**	<0.01

** - significance at 1% level of significance
* - significance at 5 % level of significance

Note: The model used for ARCH LM test $\Delta Y_t = \beta_0 + \beta_1 \Delta Y_{t-1} + \varepsilon_t$

So, now the GARCH (1, 1) model was fitted for all the price series of coffee. The GARCH model is a long memory procedure which allows the past residuals to affect the present variance directly and also indirectly. The estimated values of the parameters of the GARCH model provide an idea about the volatility present in the price series. The parameters estimated from GARCH (1, 1) are listed in Table 38.

The α and β are coefficients of ARCH and GARCH effect for the given series where α is called as ARCH parameter and β is called as GARCH parameter. The sum of α and β coefficients represent the degree of persistence of volatility and it was observed that 0.9836, 0.7413 and 0.5639 for Arabica plantation A, Arabica cherry AB, and Robusta parchment AB respectively. Compared to other

Table 38. Parameter estimates of GARCH model

Grades of coffee	α	β	$(\alpha+\beta)$	AIC	BIC
Arabica plantation A	0.981** (0.213) [<0.01]	0.002^{NS} (0.001) [0.087]	0.983	−472.469	−458.563
Arabica cherry AB	0.195** (0.063) [<0.01]	0.546** (0.125) [<0.01]	0.741	−459.866	−442.484
Robusta parchment AB	0.297* (0.127) [<0.05]	0.266* (0.135) [<0.05]	0.563	−395.188	−374.354

ss()- Standard error, []- p-value, ** - significance at 1% level of significance NS- not significant * - significance at 5 % level of significance

Note: The parameters are estimated using the equation $\sigma^2{}_t = \alpha_0 + \alpha u_{t-1}^2 + \beta\sigma_{t-1}^2$

series, prices of Arabica plantation A in Bengaluru market exhibited more volatility and persistence as the sum of the coefficients was 0.983. The results of the GARCH (1, 1) model clearly indicated that the volatility in the current period depends on volatility in the preceding period and the conditional variance for Arabica cherry AB, and Robusta parchment AB price series as evident from the significant ARCH and GARCH terms. In case of Arabica plantation A volatility in the current period depends only on volatility in the preceding period because only ARCH term was significant. The conditional standard deviation graph showing the volatility at different time periods for all three grades of coffee and they are presented in Figure 35, 36 and 37. From conditional standard deviation graph, we can conclude that volatility was high during 2005 to 2007 for Arabica plantation A, during 2014 for Arabica cherry AB and during 2001 to 2006 for Robusta parchment AB.

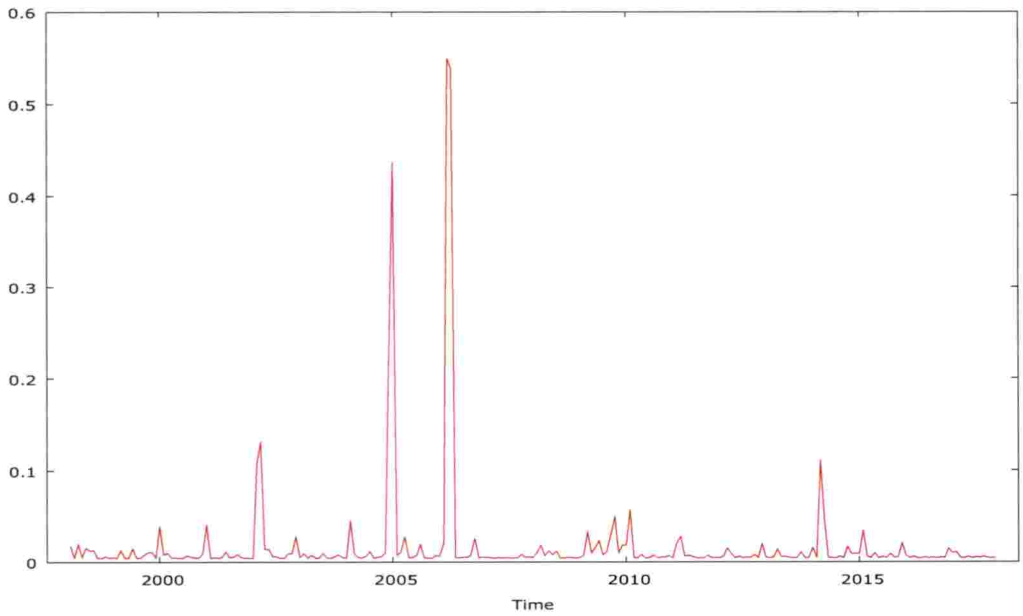

Figure 36. Conditional standard deviation graph for auction price of Arabica Plantation A.

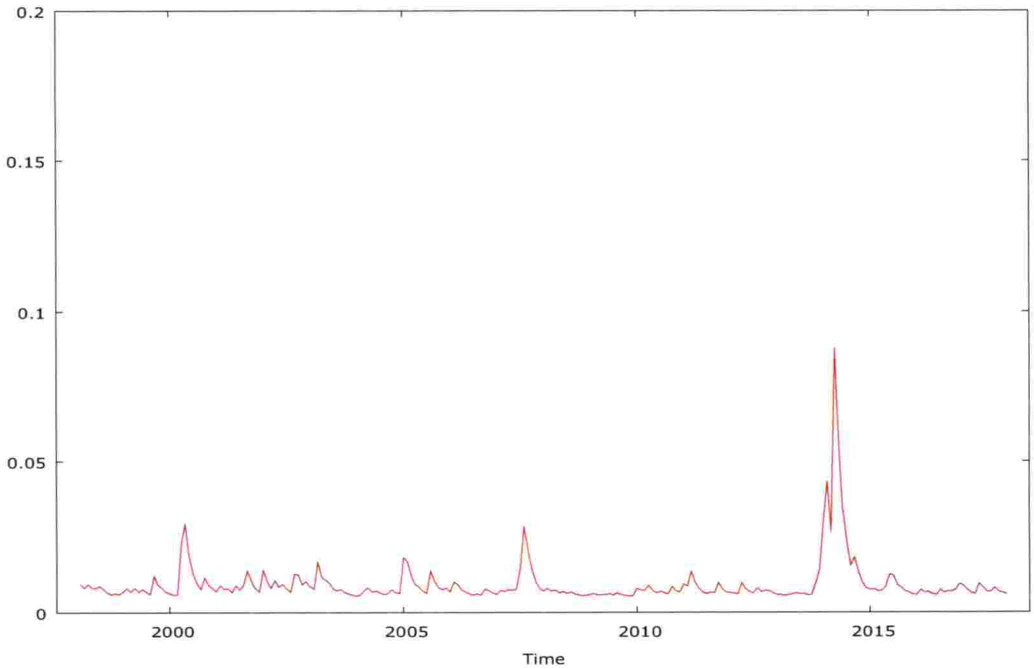

Figure 37. Conditional standard deviation graph for auction price of Arabica cherry AB.

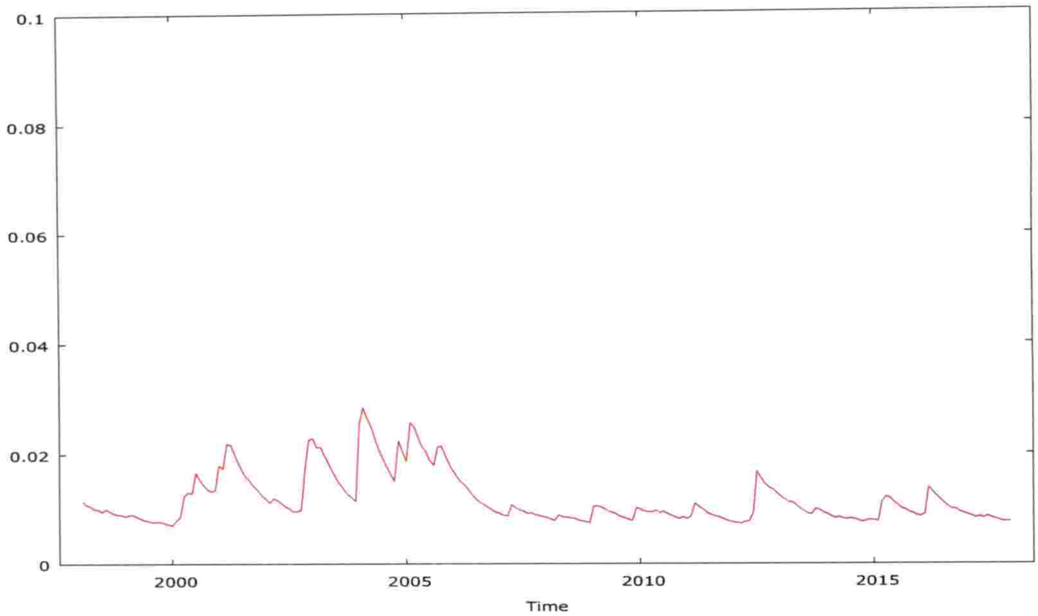

Figure 38. Conditional standard deviation graph for auction price of Robusta parchment AB.

4.4.2 Volatility of cardamom prices

To have some basic idea about the price, descriptive statistics of auction prices of cardamom in Kerala and Karnataka were calculated and is presented in Table 39. The average auction price of cardamom in Kerala (538.02 Rs kg^{-1}) was higher as compared to auction price of cardamom in Karnataka (426.56 Rs kg^{-1}). Standard deviation was highest for cardamom auction price in Kerala (270.11) as compared to Karnataka auction price (192.56). Coefficient of variation was very high for both price series i.e., 50.21 per cent for auction price of cardamom in Kerala, and 45.14 percent for auction price of cardamom in Karnataka , which indicating the high variability in auction price of cardamom in Kerala and Karnataka.

Table 39. Descriptive statistics of auction prices of cardamom in Kerala and Karnataka

Statistics	Kerala	Karnataka
Mean (Rs kg^{-1})	538.02	426.56
Std. deviation (Rs kg^{-1})	270.11	192.56
Skewness	0.95	1.08
Kurtosis	0.80	1.30
C.V	50.21	45.14

In time series analysis, assumption of stationary of the data sets is the most important. First, stationarity of both the price series of cardamom (Kerala auction price and Karnataka auction price) were tested using Augmented Dickey Fuller (ADF) test. The results of ADF test in Table 40 showed that the test failed to reject the null hypothesis of "The price series are not stationary", which indicates that both the price series were nonstationary in level form. But, the ADF test rejected the null hypothesis for differenced price series, this suggests that non-stationary series were stationary at their first difference or they are integrated of same order.

Table 40. Stationarity test for Auction Prices of cardamom

Cardamom Price	Series	ADF test	p-value
Kerala	Level	-2.227	0.196
	1st difference	-7.897	<0.01
Karnataka	Level	-2.311	0.168
	1st difference	-24.298	<0.01

Before fitting the any GARCH model it is necessary to check the presence of ARCH effect. ARCH test is done to check the presence of volatility. Mean equation is fitted and the residuals were used to check for ARCH effect by using Lagrange-Multiplier (LM) test. The Lagrange-Multiplier (LM) test statistics along with p-values are presented in Table 41.

Table 41. Results of Lagrange-Multiplier test on cardamom.

Series	LM test statistic	p-value
Kerala	11.052*	<0.05
Karnataka	20.947**	<0.01

** - significance at 1% level of significance
* - significance at 5 % level of significance

Note: The model used for ARCH LM test $\Delta Y_t = \beta_0 + \beta_1 \Delta Y_{t-1} + \varepsilon_t$

So, now the GARCH (1, 1) model was fitted for both the price series of cardamom. The estimated values of the parameters of the GARCH model provide the idea about the volatility present in the auction price of cardamom. The parameters estimated for GARCH (1, 1) are listed in Table 42.

Table-42. Parameter estimates of GARCH model

Series	α	β	$(\alpha+\beta)$	AIC	BIC
Kerala	0.094 (0.051) [0.066]	0.656** (0.157) [<0.01]	0.750	−590.233	567.366
Karnataka	0.306** (0.095) [0.001]	0.620** (0.132) [<0.01]	0.927	−336.094	−317.024

()- Standard error, []- p-value ** - significance at 1% level of significance

* - significance at 5 % level of significance

The parameters are estimated using the equation $\sigma^2{}_t = \alpha_0 + \alpha u_{t-1}^2 + \beta\sigma_{t-1}^2$

The 'α' and 'β' terms indicates the ARCH and GARCH effect for the given series where α is called as ARCH parameter and β is called as GARCH parameter. The sum (α+β) of their coefficients represents the degree of persistence of volatility. It was reported as 0.750 and 0.927 for auction price in Kerala and Karnataka respectively. Compared to Kerala price, Karnataka price series of cardamom exhibited more volatility with a value equal to 0.927, which means that any shock to the economy persist for long period. The results of the GARCH (1, 1) model clearly indicated that the volatility in the current period depends on volatility in the preceding period and the conditional variance for auction price in Karnataka as evident from the significant ARCH (0.306) and GARCH (0.620) terms. In case of Kerala, volatility in the current period depends only on conditional variance of preceding period as evident from the significant GARCH (0.656) term. The conditional standard deviation graph showing the volatility at different time periods for cardamom auction price in Kerala and Karnataka are presented in Figure 38 and 39. From conditional standard deviation graph, we can conclude that volatility was high during 1996, 1998-1999 and 2006-07 in auction price of cardamom in Kerala. However the volatility pattern of auction price of cardamom in Karnataka was entirely different. Extreme high volatility was noticed during the period stating from 2010 onwards.

Price volatility is a serious problem in agricultural commodities. Maurice and Davis (2011) reported that volatility was high and persistent in world coffee price using GARCH (1, 1) model. Worako *et al.* (2011) also made an attempt to quantify the volatility in the price of coffee in Ethiopia by using GARCH (1, 1) model and revealed that Coffee prices within Ethiopia were found to be more volatile than in Brazil.

Another study by Gayathri (2017), who studied the volatility in garlic price in different markets of Maharastra, showed that volatility shocks in the prices of Garlic were quite persistent for a long time in the selected markets.

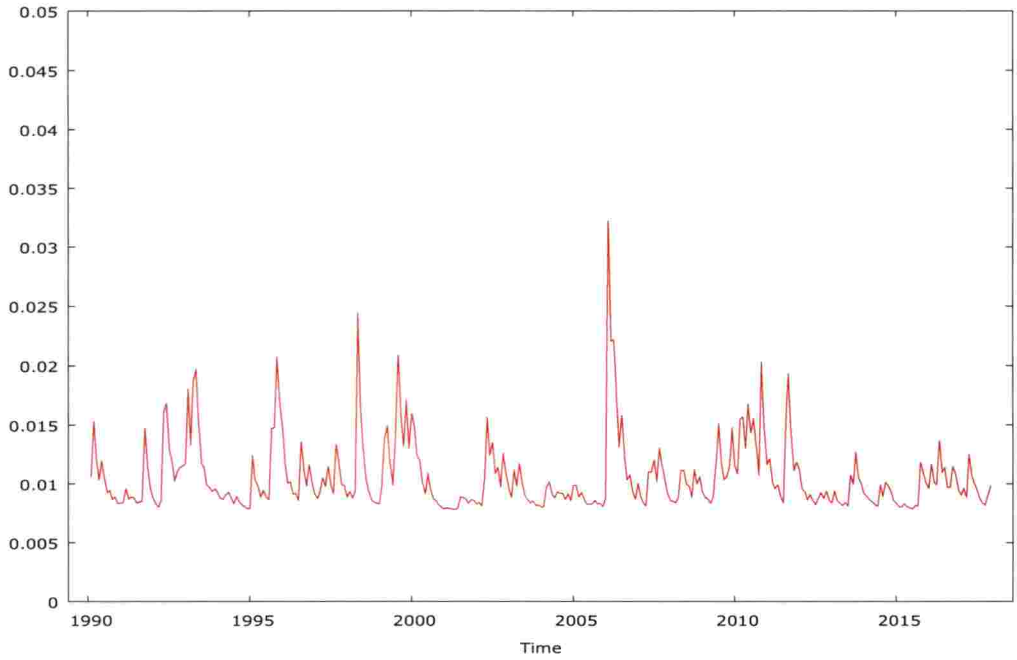

Figure 39. Conditional standard deviation graph for auction price of cardamom in Kerala.

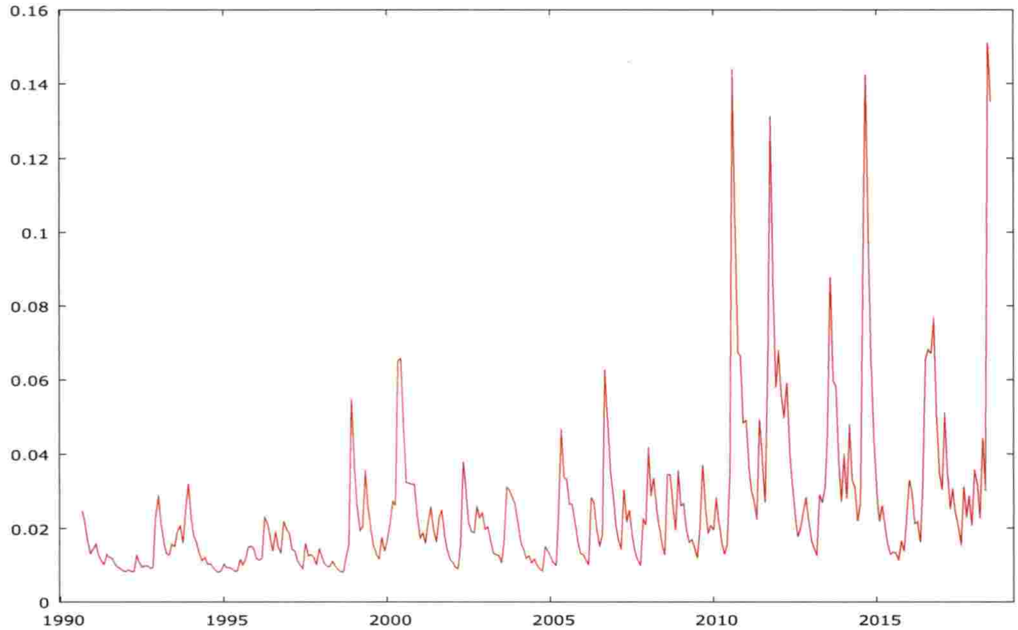

Figure 40. Conditional standard deviation graph for auction price of cardamom in Karnataka.

4.5 INFLUENCING FACTORS ON PRODUCTION

Multiple linear regressions were carried out to identify the factors responsible for production of coffee and cardamom in Kerala by using weather parameters and price.

4.5.1 Influencing factors on production of coffee

Production data from Wayanad along with weather parameters such as rainfall, temperature and relative humidity were collected for a period from 1991-92 to 2017-18. The monthly total rainfall of whole year was divided to quarterly by considering flowering period of coffee and named as RQ_{1t} (February - April), RQ_{2t} (May – July), RQ_{3t} (August – October) and RQ_{4t} (November – January). Similarly monthly average temperature and relative humidity was also divided into four quarters denoted as TQ_{1t}, TQ_{2t}, TQ_{3t} and TQ_{4t}, for temperature, RHQ_{1t} RHQ_{2t}, RHQ_{3t} and RHQ_{4t} for relative humidity. A sample data of temperature, rainfall and relative humidity from Wayanad district is presented in Table 43.

Table 43. Trends in temperature, rainfall and RH of Wayanad district (1991-2015)

year	Average temperature (°C)				Average RH (%)				Total rainfall (mm)			
	TQ_{1t}	TQ_{2t}	TQ_{3t}	TQ_{4t}	RHQ_{1t}	RHQ_{2t}	RHQ_{3t}	RHQ_{4t}	RQ_{1t}	RQ_{2t}	Q_{3t}	Q_{4t}
1991	24.45	22.82	22.03	21.15	65.42	82.59	81.92	64.70	234.00	985.02	664.00	102.60
1995	23.54	21.61	21.12	19.94	66.23	83.32	82.44	65.07	283.40	1022.20	894.40	135.30
2000	24.28	22.44	21.96	21.45	74.01	83.30	85.85	69.81	110.89	664.40	805.00	160.10
2005	24.57	22.65	21.39	20.97	80.40	89.50	90.25	81.30	204.00	1064.40	762.60	141.60
2010	24.74	23.26	22.32	21.69	74.18	86.57	87.20	74.65	118.40	873.00	507.60	284.50
2015	22.79	22.85	23.22	22.20	76.15	87.48	88.90	77.40	215.10	881.70	491.60	59.00

It is evident from Table 43 that relative humidity in second quarter (RHQ_{2t}) and third quarter (RHQ_{3t}) was varying as compared to first and fourth quarter over the years. Similarly total rainfall was very high in second and third

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quarter with a minimum of 491 mm was noticed in 2015 and a maximum of 1064mm in 2005. Multiple regression equation was estimated by taking production as dependent variable, quarterly rainfall, temperature and relative humidity as independent variables. Logarithmic values were used for estimating the regression and OLS technique was used for estimating the parameters. The results of multiple linear regressions based on ordinary least square method are presented in Table 44.

Table 44. Results of multiple linear regressions on production of coffee.

Particulars	Coefficient	Standard error	t-ratio	P value	VIF
Intercept	-5.380	22.183	-0.240	0.812	-
TQ_{1t}	2.082	2.738	0.760	0.461	2.850
TQ_{3t}	1.707	3.208	0.530	0.604	4.220
TQ_{4t}	-0.928	2.109	-0.440	0.667	3.930
RQ_{1t}	0.041	0.118	0.350	0.733	2.910
RQ_{2t}	-0.321*	0.136	-2.360	0.034	2.610
RQ_{3t}	-0.171	0.240	-0.710	0.488	2.860
RQ_{4t}	-0.012	0.063	-0.180	0.856	2.200
RHQ_{1t}	1.749*	0.769	2.280	0.040	3.170
RHQ_{2t}	-0.107	0.639	-0.170	0.869	1.420
RHQ_{3t}	0.704	2.472	0.280	0.780	9.660
RHQ_{4t}	-0.427	0.869	-0.490	0.632	5.520
Price (P_{t-1})	0.213*	0.080	2.650	0.020	1.740
Number of observations	26				
$F(12, 13)$	3.290				
R^2	0.755				
Adj. R^2	0.524				
P - value	0.021				
Durbin-Watson d-statistic(13, 26)	2.034				

*- significant at 5 % level of significance

To test the multicollinearity among the independent variables included in the regression model, variance inflation factor (VIF) was estimated and presented in the Table 39. The maximum VIF value was 9.66 for RHQ_{3t}. So, all the VIF values of independent variables were less than ten which indicated that multicollinearity was not a serious problem in the regression. Durbin – Watson test was used to check the autocorrelation. Durbin-Watson d-statistic value was 2.034, which was nearly equal to two. Hence, it can be concluded that there is no autocorrelation. The model adj. R^2 value was 0.524, which indicated that 52.4 per cent of variation in the dependent variable was explained by independent variables included in the model.

From the results, it is clear that relative humidity during February to April (RHQ_{1t}) had positive influence on production of coffee and it was significant at 5 per cent level of significance. This indicated that increase in relative humidity during this period resulted in increased production of coffee. Q_{1t} is the one of the important growth stage in coffee which coincides with blossom period of coffee. Rainfall during May to July (RQ_{2t}) had significant negative influence on production of coffee which means that excess rainfall during this period cause decrease in production of coffee. One year lag price also had significant positive influence on production of coffee in Kerala.

Other variables such as Q_{1t} and Q_{3t} temperature, Q_{1t} rainfall, Q_{3t} and Q_{4t} relative humidity had positive influence on the production of coffee but they were statistically insignificant. The remaining variables such as Q_{4t} temperature, Q_{3t} and Q_{4t} Rainfall, Q_{2t} and Q_{4t} relative humidity had a negative effect on the production of coffee and were statistically insignificant.

4.5.2 Influencing factors on production of cardamom

Production data from Idukki along with weather parameters such as rainfall, temperature and relative humidity were collected for a period from 1991-92 to 2017-18. The monthly total rainfall of whole year was divided to quarterly and named as RQ_{1t} (January - March), RQ_{2t} (April - June), RQ_{3t} (July - September) and RQ_{4t} (October - December). Similarly monthly average temperature and relative humidity was also divided into four quarters denoted as TQ_{1t}, TQ_{2t}, TQ_{3t} and TQ_{4t}, for temperature, RHQ_{1t} RHQ_{2t}, RHQ_{3t} and RHQ_{4t} for relative humidity.

A sample data of temperature, rainfall and relative humidity from Idukki district is presented in Table 45.

In Idukki district, relative humidity was almost similar in all the quarters, but total rainfall was more in fourth quarter as compared to other quarters.

Table 45. Trends in temperatre, rainfall and RH of Iduki district (1991-2015)

year	Average temperature (°C)				Average RH (%)				Total rainfall (mm)			
	TQ_{1t}	TQ_{2t}	TQ_{3t}	TQ_{4t}	RHQ_{1t}	RHQ_{2t}	RHQ_{3t}	RHQ_{4t}	RQ_{1t}	RQ_{2t}	Q_{3t}	Q_{4t}
1991	21.67	24.25	20.33	20.83	94.87	92.97	95.72	95.17	128.00	678.10	262.90	809.40
1995	21.75	22.75	21.33	21.08	79.92	88.14	92.82	87.76	75.60	573.60	299.30	926.20
2000	19.53	22.38	20.56	19.20	73.09	83.05	88.53	78.77	236.50	573.60	269.70	584.50
2005	21.80	23.77	20.48	20.91	68.63	83.69	90.24	84.61	116.20	269.06	631.80	930.90
2010	22.08	23.39	20.75	20.43	68.65	81.58	91.33	86.89	193.60	693.70	482.66	921.40
2015	20.68	21.91	20.10	21.83	94.53	95.15	95.42	94.90	49.20	708.30	528.30	721.50

Multiple regression equation was estimated by taking production as dependent variable, quarterly rainfall, temperature and relative humidity as independent variables. Logarithmic values were used for estimating the regression and OLS technique was used for estimating the parameters. The results of multiple linear regressions based on ordinary least square method are presented in Table 46.

To test the multicollinearity among the independent variables included in the regression model variance inflation factor (VIF) was estimated and presented in the Table 40. The maximum VIF value was 4.92 for RHQ_{2t}. So, all the VIF values of independent variables were less than ten which indicated that multicollinearity was not a serious problem in the regression. Durbin – Watson test was used to check the autocorrelation. Durbin-Watson d-statistic value was 1.788, which was nearly equal to two. Hence, it can be concluded that there is no autocorrelation. The model adj. R^2 value was 0.541, which indicated that 54.1%

of variation in the dependent variable was explained by independent variables included in the model.

From the results it is clear that temperature during April – June (Q_{2t}) and July – September (Q_{3t}), rainfall during April – June (Q_{2t}) had negative influence on production of cardamom. Temperature during Q_{2t} was significant at 5 per cent level of significance, temperature during Q_{3t} and rainfall during Q_{2t} were significant at 1 per cent level of significance. These results indicated that increase in temperature during Q_{2t} and Q_{3t}, excess rainfall during Q_{2t} period cause decrease in production of cardamom in Kerala.

Table 46. Results of multiple linear regressions on production of cardamom.

Particulars	Coefficient	Standard error	t-ratio	P value	VIF
Intercept	48.937	14.207	3.440	0.004	-
TQ_{1t}	-0.837	2.301	-0.360	0.722	1.630
TQ_{2t}	-7.896*	3.082	-2.560	0.024	2.040
TQ_{3t}	-9.209**	2.990	-3.080	0.009	1.300
TQ_{4t}	4.776	2.232	2.140	0.056	1.720
RQ_{1t}	0.112	0.074	1.520	0.154	1.470
RQ_{2t}	-0.597**	0.182	-3.290	0.006	1.720
RQ_{3t}	-0.183	0.357	-0.510	0.617	1.700
RQ_{4t}	0.037	0.209	0.180	0.861	1.370
RHQ_{1t}	-2.060	1.237	-1.670	0.120	4.270
RHQ_{2t}	1.584	2.407	0.660	0.522	4.920
RHQ_{4t}	1.521	2.368	0.640	0.532	4.640
Number of observations		25			
$F(11, 13)$		3.580			
R^2		0.751			
Adj. R^2		0.541			
P - value		0.016			
Durbin-Watson d-statistic(12, 25)		1.788			

*- significant at 5 % level of significance
**- significant at 1 % level of significance

Other variables such as Q_{4t} temperature, Q_{1t} and Q_{4t} rainfall, Q_{2t} and Q_{4t} relative humidity had positive influence on the production of cardamom, which were statistically insignificant. But remaining variables such as Q_{1t} temperature, Q_{3t} rainfall and Q_{1t} relative humidity had a negative effect on the production of cardamom and were statistically insignificant.

Bunn *et al.* (2014), who studied the impact of climate change on global production of Arabica and Robusta coffee, reported that higher temperatures may reduce yields of Arabica coffee, while Robusta coffee could suffer from increasing variability of intra-seasonal temperatures. Jayakumar *et al.* (2017) conducted a study to know impact of climate variability on coffee yield in Kerala and reported that blossom showers had significant influence in increasing the yield of coffee rather than total annual rainfall.

A study conducted by Amogh (2017), to find impact of climate change on pepper production reported that, increase in temperature during Q_3 (July - September) and Q_4 (October - December) resulted in decreased production of pepper in Idukki and Wayanad districts.

Summary

5. SUMMARY

Coffee is the world's supreme brewed drink. It is the second most traded commodity in the world after crude oil and most valued commodity exported by several coffee growing countries in the world. In India it is an important plantation crop, which is mainly cultivating in the southern states *viz*., Karnataka, Kerala and Tamil Nadu which accounted for 80.5 per cent of total area and 96.7 per cent of total production in India.

Cardamom (*Elettaria cardamom*) is one of the oldest known spices in the world and it is popularly known as "Queen of spices" because of its very pleasant aroma and taste. It is third most expensive spice after the saffron and vanilla. Kerala, Karnataka and Tamil Nadu are the only three states growing small cardamom in India which accounts for 100 per cent of area and 100 per cent of production to India.

The research entitled "Comparison of performance and its determinants of coffee and cardamom in South India: A statistical analysis" was conducted with the objective of comparative analysis on area, production, productivity and price of plantation crops such as coffee and cardamom across the states Kerala, Karnataka and Tamil Nadu, to develop statistical models for price volatility and to determine the factors responsible for performance.

This research work was based on secondary data on area, production and productivity of coffee and cardamom, price of different grades of coffee (Arabica plantation A, Arabica cherry AB, Robusta parchment 'AB" and Robusta cherry AB) and price of cardamom in Kerala and Karnataka for a period from 1993 to 2017, collected from Coffee Board and Spices Board, GOI. Secondary data pertaining to weather parameters such as rainfall, temperature and relative humidity (RH) were collected for Wayanad district from RARS, Ambalavayil, KAU and for Idukki district from CRS, Pampadumpara, KAU.

Different linear and nonlinear growth models were estimated to understand the trends in area, production and productivity of coffee and cardamom. Among the estimated models, best model was selected based on highest adjusted R^2, criteria of randomness and normality.

- In case of coffee, cubic model was found to be the best fitted model for predicting trends in area in Kerala, area and production in Karnataka.
- Quadratic model was found to be the best fitted model for estimating and predicting trends in area, production and productivity of coffee in Tamil Nadu, production and productivity of coffee in Kerala.
- Exponential model was found to be the best fitted model for productivity of coffee in Karnataka.
- In case of cardamom, cubic model was found to be the best fitted model for area, production and productivity in Kerala, production and productivity in Karnataka, area and production in Tamil Nadu.
- Quadratic model was found to be the best fitted model for area of cardamom in Karnataka and productivity of cardamom in Tamil Nadu.

The comparative performance in area, production and productivity of coffee and cardamom in Kerala, Karnataka and Tamil Nadu was done based on the compound annual growth rates over time.

- In Kerala, CAGR in area under Arabica coffee was negligible while area under Robusta coffee has shown an increasing trend (0.2%). Similar pattern of growth was noticed for production of Arabica coffee (-0.001%) and Robusta coffee (1.7%). However, productivity of Arabica coffee (0.8%) has shown insignificant positive CAGR, whereas Robusta coffee (1.6%) has shown significant positive CAGR. The estimated CAGR of total area (0.2%), production (1.7%) and productivity (1.6%) of coffee in Kerala was also found to be significant.
- In Karnataka, CAGR of area under Arabica coffee (0.5%) and Robusta coffee (3.1%) was found to be significant. Also, production (3.9%) and

productivity (1.2%) of Robusta coffee was positive and significant. The estimated CAGR of total area (1.8%), production (2.1%) and productivity (0.8%) of coffee in Karnataka also found to be significant.

- In Tamil Nadu, CAGR in area under Arabica coffee (0.3%) and Robusta coffee (0.2%) found to be significant and positive. Also, growth in production (1.3%) and productivity (1.2%) of Robusta coffee was found to be positive and significant. The estimated CAGR of total area (1.8%) under coffee was found to be positive and significant but, it was not significant for total production and productivity.

Kerala, Karnataka and Tamil Nadu have shown significantly increasing trends in area, production and productivity of Robusta coffee. Area under Arabica coffee was positive in Karnataka only. However, there was an increasing trend in area, production and productivity of coffee in all the three states, if we consider both varieties together.

- The estimated CAGR of area (-0.4%) under cardamom in Kerala was negative and significant but production (6%) and productivity (6.5%) have shown significant and positive CAGR.

- The estimated CAGR was negative and significant in case of area (-1%), negligible for production and positive and significant for productivity (1.5%) of cardamom in Karnataka.

- The estimated CAGR of area (-0.9%) under cardamom in Tamil Nadu was negative and significant but production (1.9%) and productivity (2.6%) have shown significant and positive CAGR.

The area under cardamom was significant and negative in all the three states and it was highest in Karnataka followed by Tamil Nadu and Kerala. Production and productivity have shown significant and positive trends in all the three states and it was highest in Kerala followed by Tamil Nadu and Karnataka. Moreover, productivity of cardamom in Kerala was two times more than productivity in Tamil Nadu and seven times larger than productivity in Karnataka.

The comovement of price of coffee and cardamom at different markets was studied using Engle-Granger cointegration technique. In case of coffee, the integration between the prices of coffee in Bengaluru and Chennai markets was tested for two grades of clean coffee namely Arabica Plantation A and Robusta Cherry AB. Also, integration between the cardamom prices in Kerala and Karnataka was tested by using auction price series.

- Stationarity of all the price series of different grades of coffee (Arabica Plantation A and Robusta Cherry AB) and cardamom were tested using Augmented Dickey-Fuller(ADF) test and the results of the analysis suggested that all the price series were stationary after first difference and integrated of order one I (1).

- The results of the cointegration analysis revealed that coffee price in Bengaluru and Chennai markets for both grades were co integrated. Similarly auction prices of cardamom in Kerala and Karnataka markets were cointegrated. These results indicated that price in markets was moving in a synchronized manner and any change in price of one market immediately be transmitted to price of the same commodity in another market.

The price volatility is the degree of variation of a price over time. In order to measure the presence of volatility in coffee and cardamom prices ARCH-GARCH model was carried out for the price of selected markets of coffee and cardamom. In case of coffee, auction price of different grades of coffee in Bengaluru market was selected for volatility analysis and volatility in cardamom price was analysed based on auction price in Kerala and Karnataka.

- The presence of ARCH effect was tested using ARCH-LM test and the results emphasize the need of ARCH-GARCH model.

- The estimated values of the parameters of GARCH model suggested that volatility was more in Arabica plantation A ($\alpha+\beta$=0.9836) as compared to Arabica cherry AB ($\alpha+\beta$= 0.74129) and Robusta parchment AB ($\alpha+\beta$= 0.56386).

- Auction price of cardamom in Karnataka had more volatility ($\alpha+\beta$=0.9265) as compared to auction price in Kerala ($\alpha+\beta$=0.7504). Moreover, volatility was high in domestic price of different grades of coffee and cardamom.

Multiple linear regressions were carried out to identify the factors responsible for production of coffee in Kerala by taking production as dependent variable, quarterly rainfall, temperature, relative humidity and one year lagged price as independent variables. In case of cardamom, production as dependent variable and quarterly rainfall, temperature and relative humidity as independent variables.

- Relative humidity during February to April (Q_1) had positive influence on production of coffee and it was significant at 5 per cent level of significance. This indicated that increase in relative humidity during this period resulted in decrease in production of coffee. Q_1 is the one of the important growth stage in coffee which coincides with blossom period of coffee. Rainfall during May to July (Q_2) had significant negative influence on production of coffee which means that excess rainfall during this period cause decrease in production of coffee. One year lag price also had significant positive influence on production of coffee in Kerala.

- Temperature during April – June (Q_2) and July – September (Q_3), rainfall during April – June (Q_2) had negative influence on production of cardamom. Temperature during Q_2 was significant at 5 per cent level of significance, temperature during Q_3 and rainfall during Q_2 were significant at 1 per cent level of significance. These results indicated that increase in temperature during Q_2 and Q_3, excess rainfall during Q_2 period cause decrease in production of cardamom in Kerala.

5.1 SUGGESTIONS

- Trend models provide clear picture of magnitude of fluctuations in production of commodities in the states. The results may be useful for planning commission for effective implementation of agricultural and horticultural developmental programmes.
- The present study is based on coffee and cardamom only. There is huge scope for undertaking further studies on other important crops.
- In this study monthly data was used for fitting ARCH or GARCH models, even weekly or daily data could be used in fitting models.
- Forecasting the price volatility of other major commodities would be helpful for government to take decision on proper marketing and price stabilization policies.

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Abstract

COMPARISON OF PERFORMANCE AND ITS DETERMINANTS OF COFFEE AND CARDAMOM IN SOUTH INDIA: A STATISTICAL ANALYSIS

By

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ABSTRACT

The research entitled "Comparison of performance and its determinants of coffee and cardamom in South India: A statistical analysis" was conducted with the objective of comparative analysis on area, production, productivity and price of plantation crops such as coffee and cardamom across the states Kerala, Karnataka and Tamil Nadu, to develop statistical models for price volatility and to determine the factors responsible for performance. This research work was based on secondary data on area, production, productivity, price of different grades of coffee (Arabica plantation A, Arabica cherry AB, Robusta parchment 'AB" and Robusta cherry AB) and price of cardamom in South India for a period from 1993 to 2017, collected from Coffee Board and Spice Board, GOI. Secondary data pertaining to weather parameters such as rainfall, temperature and relative humidity (RH) were collected for Wayanad district from Regional Agricultural Research Station (RARS), Ambalavayil, KAU and for Idukki district from Cardamom Research Station (CRS), Pampadumpara, KAU.

Different linear and nonlinear growth models were estimated to understand the trends in area, production and productivity and the best model was selected based on adj. R^2, criteria of randomness and normality. Cubic model was found to be the best fitted model for area in Kerala, area and production in Karnataka and quadratic model for area, production and productivity in Tamil Nadu, production and productivity in Kerala for coffee. Exponential model was found to be the best model for productivity of coffee in Karnataka. In case of cardamom, cubic model was found to be the best model for area, production and productivity in Kerala, production and productivity in Karnataka, area and production in Tamil Nadu and quadratic model for area in Karnataka, productivity in Tamil Nadu.

Comparative analysis on area, production and productivity of coffee and cardamom in Kerala, Karnataka and Tamil Nadu was done by estimating the compound annual growth rate (CAGR) using exponential model $Y_t = b_0 e^{(b_1 t)}$. The

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estimated CAGR of area (0.2%), production (1.7%) and productivity (1.6%) of coffee in Kerala, area (1.8%), production (2.1%) and productivity (0.8%) in Karnataka and area in Tamil Nadu (0.3%) was found to be positive and significant. In case of cardamom, significant negative CAGR was noticed in area (0.4%) whereas; significant positive high CAGR was noticed for production (6.0%) and productivity (6.5%) in Kerala. Same pattern of growth rate was noticed in Tamil Nadu. Moreover, negative significant CAGR in area (1.0%) and positive significant CAGR in productivity (1.5%) were recorded for cardamom in Karnataka.

Stationarity of all the price series of different grades of coffee (Arabica Plantation A and Robusta Cherry AB) and cardamom were tested using Augmented Dickey-Fuller (ADF) test and the results of the analysis suggested that all the price series were stationary after first difference and integrated of order one I (1). Engle-Granger co-integration technique was used to understand market integration or co-movement of prices in Bengaluru and Chennai markets for two grades of coffee and integration between cardamom auction prices in Kerala and Karnataka markets. The results of the cointegration analysis revealed that coffee prices in Bengaluru and Chennai markets for both grades were cointegrated and also cardamom auction prices in Kerala and Karnataka markets were cointegrated. These results indicated that prices in these markets were moving in a synchronized manner.

ARCH-GARCH modeling was carried out to estimate the volatility of price of coffee in Karnataka and price of cardamom in Kerala and Karnataka based on auction prices of different grades of coffee and small cardamom. The presence of ARCH effect was tested using ARCH-LM test and the results emphasizes the need of ARCH-GARCH model. The estimated values of the parameters of GARCH model suggested that volatility was more in Arabica plantation A ($\alpha+\beta$=0.9836) as compared to Arabica cherry AB ($\alpha+\beta$= 0.74129) and Robusta parchment AB ($\alpha+\beta$= 0.56386). Auction price of cardamom in Karnataka had more volatility ($\alpha+\beta$=0.9265) as compared to

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auction price in Kerala ($\alpha+\beta$=0.7504). Moreover, volatility was noticed and high in domestic price of different grades of coffee and cardamom.

Multiple linear regressions were carried out to identify the factors responsible for production of coffee in Kerala by using weather parameters and price. Average RH during February-April (Q_1) and one year lag price (P_{t-1}) had significant positive influence and rainfall during May- July (Q_2) had significant negative influence on coffee production in Kerala. But in the case of cardamom, temperature during April-June (Q_2), July-September (Q_3) and rainfall during April-June (Q_2) had significant negative influence on production.

Quadratic and cubic models were found to be the best model for trends in area, production and productivity of coffee and cardamom. Coffee had positive growth rates in area, production and productivity; however cardamom exhibited negative growth rates in area and positive growth rates in production and productivity across three states. Even though, there was a decline in area under cardamom, increasing trend in production was noticed. The remarkable achievement in the production of cardamom was due to positive growth and high productivity per hectare. The results of cointegration analysis suggest that, any change in price on account of internal or external shocks to the economy in one market would have transmitted immediately to the other markets. Price of different grades of coffee in Kerala and Tamil Nadu and auction price of cardamom in Kerala and Karnataka were cointegrated. Volatility was present and persistent in auction price of coffee in Karnataka, cardamom in Kerala and Karnataka. Persistence of volatility in the auction price of coffee and cardamom would adversely affect the income and livelihood security of the farmers.