Growth, Volatility and Productivity

of

Indian Agriculture: A Crop Wise Study

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By

Dipyaman Pal

Department of Economics

Jadavpur University

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Certified that the Thesis entitled

Growth, Volatility and Productivity of Indian Agriculture: A Crop Wise Study submitted by me for the award of the Degree of Doctor of Philosophy in Arts at Jadavpur University is based upon my work carried out under the supervision of Professor Arpita Ghose of Department of Economics and that neither this thesis nor any part of it has been submitted before for any degree or diploma anywhere/elsewhere.

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Department of Economics — Dipyaman Pal
Jadavpur University
Kolkata, India
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Content

Chapter 1

Motivation and the Relevance of the study

1.1 Introduction

Agricultural sector is the mainstay of the Indian economy, contributing about 15 per cent of national Gross Domestic Product (GDP) and more importantly, about half of India's population is wholly or significantly dependent on agriculture and allied activities for their livelihood (GOI, 2011). The contribution of agricultural sector to GDP has continued to decline gradually over the years. In 1970-71 agriculture contributed about 44 percent of GDP, which declined to 31.4 percent and 14.6 percent in 1990-91 and 2009-10 (at 2004-05 prices), respectively (CSO, 2011). It further declined to 13.9% in 2013-14. The growth rate of agriculture GDP in the last decade declined from 3.62% during 1984-85 to 1995-96 to less than 2% in the period from 1995-96 to 2004-05 and 0.91% in 2012-13. Further, state-wise trends indicate that the largest slump occurred in those areas/states that are predominantly rainfed (Planning Commission, Agriculture Strategy for Eleventh Plan: Some critical issues).

Over the past two decades the budgetary subsidies to agriculture have increased from around 3% of agriculture GDP in 1976-1980 to about 7% in 2001-03. During the same period, public investment in agriculture declined from 3.4% of agriculture GDP to 1.9%. Most of the subsidies are on fertilizer, power and irrigation water. Further, a considerable amount of Plan expenditure on agriculture is not on investment but on subsidies. The share of public expenditure on agriculture and allied sectors has been declined from 6 % in 6th Plan to 4.5 % in Tenth plan. During 11th Plan allocation of public sector resources for agriculture and allied activities has increased from Tenth Plan realization level of Rs.60,702 crore, to Rs. 1,36,381 crore (at 2006-07 prices) by the Centre, States and UTs (GOI, 2011). Rashtriya Krishi Vikas Yojana (RKVY) was introduced in the 11th Five-Year Plan to make higher investment in agriculture by the states. The RKVY, which provides sufficient flexibility to the States to take into account local needs, has helped in increasing allocation to agricultural sector. The public spending on agriculture research, education and extension should increase because (i) public spending for this purpose has high value of marginal product based internal rate of return ranging from about 21 percent to 46 percent (Desai and Namboodiri 1997 and Chand, et. al. 2011), (ii) it is not possible to increase the number of extension worker to the desired extent due to the limited budget of this sector, and (iii) it is further needed to undertake development and transfer of location specific new technologies by re-orienting Indian Council of Agricultural Research's (ICAR) research and SAUs' higher education (Pal and Singh, 1997 and Challa et. al. 2011). Thus, the public expenditure on agricultural research and education including extension; irrigation and flood control; soil and water conservation; rural infrastructure, rural financial institutions, and rural development and poverty alleviation programmes must be priorized for higher agricultural growth. Moreover, since yield gaps vary considerably from crop-to-crop and from region-to-region, the 11^{th} plan strategy must focus on specific requirements of each agro-climatic region and will require much stronger linkages between Research extension and farmers (Planning Commission, Agriculture Strategy for Eleventh Plan: Some critical issues).

In recent times policy planners and research scholars are concerned about the higher growth in agriculture and assume great importance. (Chand et al., 2007; Bhalla and Singh, 2009; Reddy and Mishra, 2009; Vaidyanathan, 2010). In fact during 1980s at the national level, the growth performance of agriculture was splendid and due to reduction in and/or stagnation of public expenditure on agricultural infrastructure, defunct extension services and biased economic reforms it decelerated during 1990s. (Thamarajakshi, 1999; Balakrishnan, 2000; Hirashima, 2000; Mahendradev, 2000; Vyas, 2001). However, through various development programmes such as interest subvention on crop loans, the National Food Security Mission, the National Agriculture Development Programme and the Pulses Development Programme which are likely to affect agricultural growth and farmers' income in the country by providing greater flexibility to the state governments to allocate resources to the priority areas of development, there has been a renewed policy thrust from the government since mid 2000s to revive agricultural growth (Rashtriya Krishi Vikas Yojana).

In the period after 1990's, there is a significant departure from the past in 1991when Government introduced process of economic reforms, which involved deregulation, reduced government participation in economic activities, and liberalization. Though much of the reforms were not initiated to directly affect agricultural sector, the sector was affected indirectly by devaluation of exchange rate, liberalisation of external trade and disprotection to industry. Then came new international trade accord and WTO, requiring opening up of domestic market. Although initially there was positive impact of trade liberalisation on Indian agriculture but afterwards it became real threat for several commodities produced in the country. All these changes raised new challenges and provided new opportunities that required appropriate policy response. Besides, last two decades had only experienced limited price intervention, and there was a sort of policy vacuum. Because of this, there was a strong pressure on the government to come out with agriculture policy as required to provide new direction to agriculture in the new and emerging scenario. In response to this, government of India announced New Agricultural Policy in July 2000.

The salient features of the new agricultural policy are:

i) Over 4 per cent annual growth rate aimed over next two decades; ii) Greater private sector participation through contract farming; iii) Price protection for farmers; iv) National agricultural insurance scheme to be launched; v) Dismantling of restrictions on movement of agricultural commodities throughout the country; vi) Rational utilisation of country's water resources for optimum use of irrigation potential; vii) High priority to development of animal husbandry, poultry, dairy and aquaculture; viii) Capital inflow and assured markets for crop production; ix) Exemption from payment of capital gains tax on compulsory acquisition of agricultural land; x) Minimise fluctuations in commodity prices; xi) Continuous monitoring of international prices; xii) Plant varieties to be protected through a legislation; xiii) Adequate and timely supply of quality inputs to farmers; xiv) High priority to rural electrification; xv) Setting up of agro-processing units and creation of off-farm employment in rural areas.

As per the existing research the yield of major crops and livestock is much lower than that in the rest of the world. Considering that the frontiers of expansion of cultivated area are almost closed in the region, the future increase in food production to meet the continuing high demand must come from increase in yield.

For successful implementation of the Millennium Development Goals the study on individual crops is extremely urgent. Such study will highlight the crops for which the growth of output and the relative performance taking into account different indicators like the extent of volatility and productivity are satisfactory vis-a-vis the crops for which these performances are lacking. These studies thus can be taken as a guideline for framing appropriate policies towards the disadvantaged group of crops.

Volatility in agricultural sector is a very important indicator because volatility in output or the output prices may affect the supply decision of the farmer. The volatility in the agricultural sector can either come from agricultural output or price or both. Such type of volatility can be associated with a variety of factors, ranging from climate variability and change, frequent natural disasters, uncertainties in yields, weak rural infrastructure, imperfect markets and lack of financial services including limited span and design of risk mitigation instruments such as credit and insurance. Output volatility is positively correlated with negative outcomes that come from imperfectly predictable biological, climatic(rainfall), and price variables, which undermined the viability of the agricultural sector and its potential to become a part of the solution to the problem of endemic poverty of the farmers and the agricultural labor and also endangered the farmer's livelihood and incomes. Apart from these, there are some other variables like natural adversities (for example, pests and diseases) and climatic factors namely flood, drought etc. not within the control of the farmers, leading to adverse changes in both input and output prices.

The productivity growth in agriculture is very important. In the literature two concepts of productivity is often used: firstly, partial productivity which is define as the contribution of one factor/ input (say labour or capital) to output growth keeping the other factors constant. Secondly, Total Factor Productivity growth (TFPG) is a variable, which accounts for effects in total output not caused by inputs. More specifically, TFPG measures the amount of increase in total output which is not accounted for the increase in total inputs and thus measures shift in output due to the shift in the production function over time, holding all inputs constant (Abramovitz, 1956; Denison, 1962, 1967, 1985; Hayami et al, 1979). It has been widely acknowledged in the economic literature that economic growth no matter how impressive is will not be sustainable without improvement in total factor productivity growth. Growth in total factor productivity in agriculture is both necessary condition as well as sufficient condition for its development. It is a necessary condition because it enables agriculture to avoid the trap of Ricardo's law of diminishing returns. It is a sufficient condition because it increases production at a reduced unit cost in real terms (For example: Kahlon and Tyagi, 1983; Sidhu and Byarlee, 1992; Kumar and Mruthyunjaya, 1992; Rao, 1994; Kumar and Rosegrant, 1994; Sing, Pal and Moris, 1995; Acharya, 1998 etc.).

Given this background the objectives of this present thesis is to analyses the problem of **(i) growth pattern, (ii) extent of volatility in price of output** and **(iii) productivity of Indian Agriculture** for different types of crops.

1.2 Objectives of the Present Thesis

The **first problem,** the present thesis is related with growth of output. Such a study is essential given the changed scenario in Indian Agricultural Sector. Moreover, since in the Indian context climate condition varies crop-to-crop and from region-to-region, in order to have a good implementation of the crop wise study one must incorporate the state wise study as well because the performance of the crops varies among different states. So, **first of all** it is interesting to check whether the series of output of major selected crops and states converges to a path having trend preserving properties or not without the presence of structural break. The selected crops and major producing states are as below:

The selected crops are:

A. **Food crops:** Rice, Wheat, Maize, Jowar, Gram, Bajra.

For each of the crop the major states producing those crops have been considered and those states for the above mentioned crops are chosen whose share in the total production are greater than or equals to 3%.

- ✓ Rice- Andhra Pradesh (AP), Assam (AS), Bihar (BI), Haryana (HA), Karnataka (KA), Madhya Pradesh (MP), Orissa (OR), Punjab (PU), Tamil Nadu (TN), Uttar Pradesh (UP), West Bengal (WB).
- ✓ Wheat- Bihar (BI), Haryana (HA), Madhya Pradesh (MP), Rajasthan (RA), Punjab (PU), Uttar Pradesh (UP).
- ✓ Maize(Corn)- Andhra Pradesh (AP), Bihar (BI), Gujarat (GU), Himachal Pradesh (HP), Karnataka (KA), Madhya Pradesh (MP), Punjab (PU), Uttar Pradesh (UP), Rajasthan (RA).
- ✓ Jowar(Sorghum)- Andhra Pradesh (AP), Gujarat (GU), Karnataka (KA), Maharashtra (MA), Rajasthan (RA), Tamil Nadu (TN), Uttar Pradesh (UP).
- ✓ Gram- Bihar (BI), Haryana (HA), Madhya Prades (MP), Maharashtra (MA), Rajasthan (RA), Uttar Pradesh (UP).

- ✓ Bajra(Peari Millets)- Gujarat (GU), Haryana (HA), Karnataka (KA), Maharashtra (MA), Rajasthan (RA), Uttar Pradesh (UP).

B. **Cash crops or Non Food crops:** Cotton, Groundnuts, Rapeseed/Mustard Oil.
Again for each of these crops the major states producing those crops have been taken.

- ✓ Cotton- Andhra Pradesh (AP), Gujarat (GU), Haryana (HA), Karnataka (KA), Madhya Pradesh (MP), Maharashtra (MA), Punjab (PU), Rajasthan (RA).
- ✓ Groundnuts- Andhra Pradesh (AP), Gujarat (GU), Karnataka (KA), Madhya Pradesh (MP), Tamil Nadu (TN).
- ✓ Rapeseed/Mustard Oil- Assam (AS), Gujarat (GU), Haryana (HA), Madhya Pradesh (MP), Rajasthan (RA), Uttar Pradesh (UP), West Bengal (WB).

The study period is from 1970-71 to 2013-14

Then it is motivating to test whether the growth process converges to a path having trend preserving properties in presence of one time structural break for different series using Sen (2003) approach. By Bai-Perron (1998 and 2003) method this thesis also checked whether there exists any multiple structural breaks in the series or not. Regarding growth pattern one can find most of the papers are related to classical method using deterministic trend analysis [Sen, 1967; Narain, 1977; Rudra, 1982; Reddy, 1978; Das, 1978; Srinivasan, 1979; Vidyyanathan, 1980; Dandekar, 1980; Ray, 1983; Sawant, 1983; Dev, 1987; Boyce, 1987; Saha and Swaminathan, 1994; Sawant and Achuthan, 1995; Bhalla and Singh, 1997, etc] and there is a dearth in the studies using the recent time series econometric method, although some literature are available [Mukhopadhyay and Sarkar, 2001; Oehmke and Schimmelpfennig,2004; Ghose and Pal ,2007; Hossain,2008; Sengupta, Ghosh and Pal ,2009; Pal and Ghose ,2012; Pal and Ghose ,2013; etc.]. A detailed crop wise study for the Indian Agriculture using this modern time series approach is still lacking. The present thesis intends to add the literature on this issue by estimating structural break and testing for convergence of different crops using modern time series approach.

After the estimation of growth it is important to identify the reasons behind the variation in growth of output. In present study the determinants for growth has been found for all the crops included in the sample. Ideally while specifying output growth equation one should keep in mind that output growth will depend on the input growth as well as the other socio economic factors like growth of HYV uses, Government irrigation or Private irrigation, Rainfall, Government expenditure on agricultural education, research, and extension, Rural literacy, Agricultural Loan and Inequality in Distribution of Land Holding. In third problem while estimating the total factor productivity growth we have taken into account seeds, fertilizers, manure uses and human labour etc. collected from cost of cultivation data published by Government of India. However these data are not available for all the 9 crops and for all the major producing states as taken into consideration in this problem. These inputs data are available only for three crops: Rice, Wheat and Jowar for the major producing states of these crops. But since we are employing a panel approach for each of the all 9 crops including all the major producing states and for entire time point we have not included input as the determinant for crops other than Rice, Wheat and Jowar. For Rice, Wheat and Jowar we are including both the growth of inputs like fertilizers (F), manure uses (M) and human labour[1] (L) as well as the explanatory variables as discussed above. So, for these three crops Rice, Wheat and Jowar we have two sets of regression

I. Excluding the inputs
II. Including the inputs.

Among the chosen explanatory variables it is found that there exist some explanatory variables which in turn depends on the dependent variable, ie. growth of output. In the present case one of the explanatory variable taken for growth of output is the growth of HYV uses which in turn depends on the growth of output. Thus in order to explain the growth of output, one need to formulate a simultaneous equation kind of frame work.

Indian states have its uniqueness that influences the growth and performance of different crops in several counts. Thus the growth and performance of different crops in different states do not always move in the same path. As we have considered different major producing states under each crop so for analyzing the determinant of growth rate we need to construct a panel model for each of the crop.

[1] Animal labour is not included because the determinant as most of the entries under animal labour are zero or unavailable.

Thus in order to estimate the major determinants one need to construct a simultaneous kind of framework in the panel setup showing two way dependency between the dependent variable and the explanatory variable. So, to get a comprehensive picture about the possible determinants influencing growth of output of different crops a simultaneous panel regression analysis has been used in order to find out major determinants of growth for the period 1970-71 to 2013-14.

The parameters are thus estimated by considering a panel model under a seemingly unrelated regression (SUR) framework and each regression was adjusted for contemporaneous correlation (across units) and cross section heteroscedasticity. While estimating the panel model we checked whether fixed effect model is a better fitted model over the random effect model or not using Hausman test. For regression purpose this problem considers both dependent variable and explanatory variables in growth terms. The problem of identification has been checked and turned out to be over-identified.

Regarding the **second problem** of the present thesis, ie, the measurement of volatility, it can be mentioned that volatility in agriculture sector can either come from agricultural output or price or both. Such type of volatility can be associated with a variety of factors, ranging from climate variability and change, frequent natural disasters, uncertainties in yields, weak rural infrastructure, imperfect markets and lack of financial services including limited span and design of volatility mitigation instruments such as credit and insurance. Thus, measurement of output and price volatility for different crops is essential. For the measurement of volatility the earlier studies [Heady, 1952; Heady, 1961; Dandekar, 1976; Bliss and Stern, 1982; Rangaswamy, 1982; Sing and Nautiyal, 1986; Sankar and Mythili, 1987; Mosnier, Reynaud, Thomas, Lherm, Agabriel, 2009; etc.] are based on different specifications of model and estimation procedure but are devoid of the use of the modern time series technique. In-fact, the perusal of the literature reveals that there is dearth in studies relating to the measurement of volatility in the agricultural sector by using modern time series approach like autoregressive conditional heteroskedasticity model (ARCH)/ generalized autoregressive conditional heteroskedastic model (GARCH) method and the present thesis attempts to contribute to the literature in this direction.

Thus first of all it is checked whether there is any ARCH effect in the series of the growth of price indices of major selected crops or not for the period 1970-71 to 2013-14. The major selected crops and sates are already defined in the earlier problem. After checking the ARCH effect next objective is to estimate the volatility of the series of the growth of price indices of the major selected crops by applying ARCH or GARCH method. Thirdly, it is important to check whether different variety of each crop has any effect on the volatility or not. For this purpose we take growth of price of different variety of each crop for each of their major producing states and capture the effect of variety on the volatility by incorporating dummy variables corresponding to the variety of each crop in basic equation defining price volatility. Also it is interesting to check whether these varieties give more return or not.

Coming to the **third** problem which linked with Total Factor Productivity Growth (TFPG), the relevant question is whether productivity of different crops has increased or not. From 1991 onwards Government introduced process of economic reforms, which involved deregulation, reduced government participation in economic activities, and liberalization. Though much of the reforms were not initiated to directly affect agriculture sector, the sector was affected indirectly by devaluation of exchange rate, liberalization of external trade and disprotection to industry. One of the major objectives of introducing these policies is to increase productivity. Natural question arises that what is the extent of productivity for different crops. Some literature are available that measures productivity in Indian agriculture [Kumar and Rosegrant, 1994; Trueblood, 1996; Arnade, 1998; Fan, Hazell and Thorat, 1998; Murgai, 1999; Forstner et al, 2002; Bhushan, 2005; Bosworth and Collins, 2008; etc.]. Few of them adopted cropwise estimates by using Data Envelopment Analysis (DEA) and so there is dearth in the study related to the cropwise analysis of productivity by using non parametric approach. The present thesis intends to take this into account.

So the first objective of the problem related to TFPG is that to estimate the TFPG of different crops in Indian Agricultural sector for the period 1970-71 to 2013-14 by using Biennial Malmquist Index (BMI) of non-parametric method of Data Envelopment Analysis (DEA) and state level panel data.

The selected crops and major producing states are as follows:

- ✓ Rice- Andhra Pradesh, Assam, Bihar, Haryana, Karnataka, Madhya Pradesh, Orissa, Punjab, Tamil Nadu, Uttar Pradesh, West Bengal
- ✓ Wheat- Bihar, Haryana, Madhya Pradesh, Rajasthan, Punjab, Uttar Pradesh
- ✓ Jowar(Sorghum)- Andhra Pradesh, Karnataka, Maharashtra, Rajasthan and Tamil Nadu.

After finding out the extent of TFPG, the **second objective** relating to this third problem of the thesis is to decompose TFPG into its different components: technical changes, efficiency changes and scale efficiency changes to check which component dominates over the other while finding out the major sources of TFPG.

Thirdly, after finding out the extent and sources of TFPG of selected crops the thesis tries to find out the factors explaining the productivity of the selected crops. To explain the factors behind variation in productivity this study considered different infrastructural, institutional and demographic variables like growth of HYV uses, Government irrigation or Private irrigation, Rainfall, Government expenditure on agricultural education, research, and extension, Rural literacy, Agricultural Loan and Inequality in Distribution of Land Holding.

Now, TFPG is basically dependent on the growth of technology along with the other factor. In the context of agriculture one possible way is that the growth of technology can be represented by the growth of HYV uses. On the other hand, the growth of HYV uses in turns may be dependent on the TFPG itself in association with the other factors. Thus one can think of a simultaneous kind of relationship between TFPG and growth of HYV uses. Hence, the present problem uses a simultaneous panel regression model for estimating the determinants of TFPG followings the same methodology as described in the growth problem.

Finally, an interstate comparison is made on the basis of rate of growth of output, volatility and productivity values of the selected crops. Also the common factors affecting growth of output and productivity are pointed out.

1.3 The Structure of the Present Thesis

The structure of the present thesis is as follows:

Chapter 1 Presents the introduction and the relevance of the present study.

Chapter 2 Discusses survey of literature highlighting the gaps and presents the connection of the present thesis with the existing literature.

Chapter 3 Analyses growth performance of Indian Agricultural Sector for major selected crops like Rice, Wheat, Maize, Jowar, Gram, Bajra, Cotton, Groundnuts and Rapeseed/Mustard Oil, tests for convergence, existence of structural break and determine the factors responsible for growth of output by forming and estimating a simultaneous panel model after taking into account the interdependence between the growth of output and the growth of HYV uses.

Chapter 4 Measure the volatility of the growth of price in case of different crops in Indian Agriculture by applying ARCH/GARCH method and also found out volatility of the growth of price in case of different crops and states by including different variety of crops by ARCH/GARCH method.

Chapter 5 Estimates Total Factor Productivity Growth of Indian Agricultural Sector considering each major selected state as a producing unit using Data Envelopment Analysis approach.

Decomposition of TFPG into its different components: technical changes, efficiency changes and scale efficiency changes to check which component dominates over the other while finding out the major sources of TFPG.

Also the factors behind the variation in Total Factor Productivity Growth are identified using a simultaneous panel approach.

Chapter 6 Compares between Growth of Output, Volatility and Total Factor Productivity Growth of Indian Agricultural Sector and tries to identify the common factors responsible for changes in Growth of output and Total Factor Productivity Growth.

Chapter 7 Draws some concluding remarks over the whole study

Chapter 2

Survey of Literature

2.1 Introduction

The study relating to agriculture are quite vast and are connected with different issues like estimation of production function, cost function, growth analysis, relation between farm size and productivity, farm supply response function, efficiency analysis, productivity analysis, issues relating to uncertainty and risk among others. It has been already highlighted in chapter 1 that the present thesis is concerned with (i) growth pattern, (ii) extent of volatility of price of output and (iii) productivity of Indian agriculture for different crops. Thus to keep the task with manageable limit the Chapter presents the survey relating to growth, volatility and productivity relating to agriculture around the globe as well as in Indian context.

The chapter is organized as: **Section 2.2** represents the Survey of Literature relating to the growth of agricultural sector. **Section 2.3** discusses Studies on volatility. **Section 2.4** discusses studies on total factor productivity growth relating to the agricultural sector. The Connection of the Present Study with the Existing Literature is presented in **Section 2.5.**

2.2 Survey of Literature Relating to the Growth of Agricultural Sector:

2.2.1 Econometric Theoretical Studies Relating to Testing for Structural Break:

If we go through the survey of literature, we find some studies where the researchers have empirically done the Unit Root hypothesis and Structural Break analysis using any of the existing methodologies (by curve-fitting or by traditional trend analysis technique) and concluded accordingly. With concrete empirical supports, some researchers have developed alternative theories of testing Unit Root hypothesis. Now according to the survey of literature there exists two kind of structural break analysis: first single structural break and second multiple structural breaks analysis. The subsequent sub-sections contain some important econometric theoretical studies relating to analysis of true nature/trend of macroeconomic time series using structural break procedure.

2.2.1.1 Econometric Theoretical Studies Relating to Single Structural Break

Traditionally it is viewed that any random shock only have a temporary effect on macroeconomic time series and in long run the movement of the series remains unaltered since the series generally follows Trend Stationary Process and one can reject the presence of a Unit Root in the series. To test the Unit Root hypothesis some alternative approaches are developed. In this area some important works are done by Samuelson (1973), Hall (1978), Blanchard and Summers (1986), Nelson and Plosser (1982), Stulz and Wasserfallen (1985), Wasserfallen (1986), Champbell and Mankiw (1987, 1988), Clark (1987), Cochrane (1988), Shapiro and Watson (1988), Christiano and Eichenbaum (1989), Perron (1989), Zivot and Andrews (1992), Christiano (1992), Perron and Vogelsang (1992), Perron (1997), Vogelsang and Perron (1998), Sen(2003).

Samuelson (1973) tests Unit Root hypothesis on stock prices, **Gould and Nelson (1974)** on velocity of money, **Hall (1978)** on consumption series, **Blanchard and Summers (1986)** on employment. All of them apply different methods of traditional testing procedure and launch a series of theoretical investigations with consistent implications of the presence of Unit Root.

The traditional view, which claimed the presence of deterministic trend in most macroeconomic series, is boldly challenged by **Nelson and Plosser (1982).** In their seminal study, using statistical techniques (Dickey-Fuller test) developed by **Dickey and Fuller (1979, 1981),** they argue with empirical evidence that current shocks have a permanent effect in the long run on most macroeconomic and financial time series. Notably, later the Dickey-Fuller test is modified to Augmented Dickey-Fuller test by **Said and Dickey (1985),** where the series follows autoregressive moving average process.

Stulz and Wasserfallen (1985) and **Wasserfallen (1986)** apply similar methodology as Nelson and Plosser have used, to other economic series and reaffirm the conclusion of stochastic trend in respective economic time series under consideration.

Champbell and Mankiw (1987, 1988), Clark (1987), Cochrane (1988), Shapiro and Watson (1988) and **Christiano and Eichenbaum (1989)** test the Unit Root hypothesis on different macroeconomic time series. According to them, current shocks are a combination of temporary and permanent shocks and in long run the response of a series to a random shock depends on the relative importance/size of these two types of shocks.

Perron (1989) tries to assess carefully the reliability of the Unit Root hypothesis as an empirical fact. He performs the Unit Root hypothesis taking different economic time series conditional on a known break point. Comparing the empirical results with his asymptotic critical values he concludes that most macroeconomic time series do not have Unit Root and the fluctuations are transitory in nature. Only the Great Crash of 1929 and the Oil Price Shock of 1973 have had a permanent effect on various macroeconomic variables.

Criticizing Perron's method of Unit Root test, which assumed the location of break by visually inspecting a plot of the time series, a number of studies develop. Along with the path-breaking paper by Zivot and Andrews (1992), other worth-mentioning studies are by Christiano (1992), Perron and Vogelsang (1992), Perron (1997), Vogelsang and Perron (1998). They all adopt Perron's methodology (1989) for each possible break date in the sample i.e., the breaks are considered to be endogenous in nature.

Interestingly, **Zivot and Andrews (1992)** also argue against the exogeneity assumption concerning the Great Depression (1929) and the Oil Crisis (1973). They argue that Perron's choice of break points was based on prior observation of data. Zivot and Andrews transform the whole testing procedure into an unconditional Unit Root test. They consider the break points as endogenous and allow for an estimated break in the trend function under the alternative hypothesis. Then comparing the empirical findings with their own-constructed asymptotic critical values they cannot reject the Unit Root hypothesis at 5% level for four of the ten Nelson and Plosser series, whereas, these four series are rejected by Perron in his own study.

Christiano (1992) tests Unit Root hypothesis on post-war quarterly real GNP series applying bootstrap methods. He cannot reject the Unit Root null for this particular time series.

It can be mentioned here that different statistical tools are developed by Phillips and Durlauf (1986), Engle and Granger (1987), Stock and Watson (1988) suitable for more general models such as the co-integration framework, multivariate systems with integrated variables. Other studies related to determination of estimated structural breaks and requisite asymptotic distribution theory for Unit Root tests in time series models are presented by Rappoport and Reichlin (1989), Rappoport (1990) and Banerjee, Dolado and Galbraith (1990).

Sen (2003) studied the power properties of SupWald test or the maximum F statistic proposed by Murray (1998) and Murray and Zivot (1998) and found that the power of maximal F statistic is less erratic and can be greater than the mixed model minimum t statistics. Sen also reports that the Unit Root null hypothesis can be rejected for all Nelson Plosser series except GNP deflator, consumer prices, velocity and interest rate.

Arai and Kurozumi (2007) proposed residual-based tests for the null hypothesis of cointegration with a structural break against the alternative of no cointegration. The Lagrange Multiplier (LM) test is proposed and its limiting distribution is obtained for the case in which the timing of a structural break is known. Then the test statistic is extended to deal with a structural break of unknown timing. The test statistic, a plug-in version of the test statistic for known timing, replaces the true break point by the estimated one. They showed the limiting properties of the test statistic under the null as well as the alternative. Critical values are calculated for the tests by simulation methods. Finite-sample simulations show that the empirical size of the test is close to the nominal one unless the regression error is very persistent and that the test rejects the null when no cointegrating relationship with a structural break is present.

Sen (2009) argued that the unit root tests of Perron were designed to have power against the stationary alternative characterized by a break in the trend function. He showed that all versions of Perron’s (1989) tests can be over-sized when there is a break in the innovation variance. He propose modified Perron statistics based on the GLS transformation proposed by Kim, Leybourne, and Newbold that maintain size and have power against the trend-break stationary alternative. The modified Perron statistics weakens evidence against the unit root null for the Nelson-Plosser macroeconomic series.

2.2.1.2 Econometric Theoretical Studies Relating to Multiple Structural Break

Recently some literatures are developed for estimating the multiple structural breaks in the macroeconomic series. Some literature are available on both empirical and theoretical estimation procedure of the multiple structural breaks. The literature which deals with the theoretical method related to the multiple structural breaks analysis are due to Andrews, Lee, and Ploberger (1996), Garcia and Perron (1996), Lumsdaine and David H. Papell (1997), Liu, Wu, and Zidek (1997), Bai and Perron (1998), Bai and Perron (2003), Pesaran ,Pettenuzzo And Timmermann (2006) among other.

Andrews, Lee, and Ploberger (1996) considered optimal tests in the linear model with known variance. **Garcia and Perron (1996)** use the sup Wald test for two changes in a dynamic time series. **Lumsdaine and David H. Papell (1997)** allowing for the possibility of two endogenous break points, and they found more evidence against the unit-root hypothesis than Zivot and Andrews, but less than Perron.

Another study by **Liu, Wu, and Zidek (1997)** considered multiple shifts in a linear model estimated by least squares. They study the rate of convergence of the estimated break dates, as well as the consistency of a modified Schwarz model selection criterion to determine the number of breaks. Their analysis considers only the so-called pure-structural change case where all the parameters are subject to shifts.

Bai and Perron (1998) considered issues related to multiple structural changes, occurring at un-known dates, in the linear regression model estimated by least squares. The main aspects of their paper are the properties of the estimators, including the estimates of the break dates, and the construction of tests that allow inference to be made about the presence of structural change and the number of breaks. Furthermore, they consider the more general case of a partial structural change model where not all parameters are subject to shifts. A partial change model is useful in allowing potential savings in the number of degrees of freedom, an issue particularly relevant for multiple changes. Also they study both fixed and shrinking magnitudes of shifts and obtain the rates of convergence for the estimated break fractions and proposed a procedure that allows one to test the null hypothesis of, say, I changes, versus the alternative hypothesis of I + 1 changes. This is particularly useful in that it allows a specific to general modeling strategy to consistently determine the appropriate number of changes present. An estimation strategy for which the location of the breaks need not be simultaneously determined is discussed. Instead, our method successively estimates each break point. They also allows for general forms of serial correlation and heteroskedasticity in the errors, lagged dependent variables, trending regressors, as well as different distributions for the errors and the regressors across segments.

Bai and Perron (2003) consider practical issues for the empirical applications of the procedures. They first addressed the problem of estimation of the break dates and present an efficient algorithm to obtain global minimizers of the sum of squared residuals. This algorithm is based on the principle of dynamic programming and requires at most least-squares operations of order O (T^2) for any number of breaks. Their method can be applied to both pure and partial structural change models. Second, they consider the problem of forming confidence intervals for the break dates under various hypotheses about the structure of the data and the errors across segments. Third, they address the issue of testing for structural changes under very general conditions on the data and the errors. Fourth, they consider the issue of estimating the number of breaks.

Pesaran ,Pettenuzzo And Timmermann (2006) provides a new approach to forecasting time series that are subject to discrete structural breaks. they proposed a Bayesian estimation and prediction procedure that allows for the possibility of new breaks occurring over the forecast horizon, taking account of the size and duration of past breaks (if any) by means of a hierarchical hidden Markov chain model. Predictions are formed by integrating over the parameters from the meta-distribution that characterizes the stochastic break-point process.

2.2.2 Empirical Literature Related to Structural Breaks in the Agricultural Sector in International Context

Recently some literatures are developed for estimating the structural break in the agriculture sector. The literatures which deals with the empirical application related to the structural break analysis in agricultural sector in international context are very few[1] in number.

[1] The empirical application of structural break is found in other streams of economics. But those studies are not preview in this thesis. So I am not including those studies in this chapter.

Among them, Yao (1996), Ben-David, Lumsdaine and Papell (2003), Miljkovic and Paul (2003), Oehmke and Schimmelpeennig (2004), Dawson, Sanju´an, and White (2006), Hossain (2008), Frank and Garcia (2009), Lee and Hsu (2009), Jin and Miljkovic (2010), Shahraki and Abbasian (2014) and many more are important one.

Yao (1996) constructed a VAR model to study the sectoral cointegration relationship in China. As a primary sector of the economy, agriculture is found to be a growth engine throughout the data period 1952- 92 although its contribution to GDP declined steadily over time. This evidence is consistently found in both the long-run and the short-run models of a VAR. In contrast, the growth of non-agricultural sectors had little effect on agriculture in 1952-77. However, a structural break is found under the economic reforms (1977- 92) when industry and other non-agricultural sectors started to cause agriculture to grow.

Ben-David, Lumsdaine and Papell (2003) provide evidence on the unit root hypothesis and long-term growth by allowing for two structural breaks. They reject the unit root hypothesis for three-quarters of the countries approximately 50% more rejections than in models that allow for only one break. While about half of the countries exhibit slowdowns following their postwar breaks, the others have grown along paths that have become steeper over the past 120 years. They found that the majority of the countries, including most of the slowdown countries, exhibit faster growth after their second breaks than during the decades preceding their first breaks.

Miljkovic and Paul (2003) argued that trade creation in agricultural products is defined as a statistically significant positive break in the trend function of the growth in exports and imports between member countries. They attempted to determine the time of any break in the trend of real exports and imports between the Canada–USA Free Trade Agreement (CUSTA) and the North American Free Trade Agreement (NAFTA) member countries for the years 1980:I through 1999:II, and document the scale of the phenomenon. They found that trade creation only occurs in USA agricultural exports to Canada because of CUSTA. The results confirm the theory that the regionalism of NAFTA did not lead to regionalization or an increasing share of intraregional international trade.

Oehmke and Schimmelpeennig (2004) measure structural changes as statistically significant breaks in either stochastic or deterministic time trends, and apply these measures to agricultural productivity and research. Productivity has a break in 1925 accompanying agriculture's early experience with the Great Depression. Research trends shifted in 1930 as the Depression and new technology began to strongly influence efficient farm size and capitalization. After modeling lags between research and productivity impacts in a vector autoregression (VAR), they compare their results to their earlier work by developing a procedure to estimate the rate of return to research from the impulse response function of the VAR.

Dawson, Sanju´an, and White (2006) while examining the Co-movement between futures prices when commodities are substitutes, re-examined using Johansen, Mosconi, and Nielsen's co-integration procedure that permits structural breaks. Results show evidence of co-integration and hence price discovery. There is a significant break in October 2000 following Common Agricultural Policy intervention price reductions, the barley–wheat futures market is perfectly integrated, and the barley price Granger-causes the wheat price. Modeling structural breaks in price relationships appears important.

Hossain (2008) investigates the trends and movements of agricultural prices, industrial prices and the agricultural terms of trade in Bangladesh with annual data for the period 1952–2006. The ADF and KPSS tests results suggest that both agricultural and industrial prices have a unit root while the agricultural terms of trade is trend-stationary. These results remain unchanged if allowance is made in the unit root test for the possibility of a structural break during 1971–1975 (when Bangladesh gained independence from Pakistan and experienced economic shocks) by applying the two-step procedure of Perron (1989). A simple Nerlovian agricultural price determination model is specified within the framework of aggregate demand and aggregate supply. The Johansen cointegration test results for the periods 1953–2006 and 1973–2006 suggest that there exists a cointegral relationship between agricultural prices, industrial prices, *per-capita* real income and the real exchange rate between the Bangladeshi *taka* and the US dollar under the restriction that *per-capita* real income and the real exchange rate are 'long-run forcing variables' in the sense of Pesaran and Shin (1995), and Pesaran, Shin and Smith (1996).The paper also estimates a four-variable vector error-correction (VEC) model and conducts an impulse response analysis for the post-independence period, 1973–2006.

Frank and Garcia (2009) provided mixed results regarding the presence of a time varying risk premium in agricultural futures markets. They test for the presence of a time-varying risk premium focusing on the properties of the underlying data. Their results show that accounting for the structural break in the 1970s plays a key role in the findings. They find only limited evidence of time-varying risk premium. For a two-month horizon the corn, soybean meal and hog markets show no signs of a risk premium, while very weak support for a time-varying premium emerges in live cattle. For the four-month horizon, no evidence of a time-varying risk premium appears for any of the markets.

Lee and Hsu (2009) used time-series data for Taiwan's agricultural sector and with the government's public investment in the agricultural sector serving as a proxy variable for nonfarm current inputs aside from the original labour and capital input variables usually taken into consideration, they also examine the relationship between public investment in agriculture (public investment/land) and agricultural land productivity (output/land) in Taiwan. Their main findings are as follows. First, the cointegration test reveals that public investment in agriculture and the productivity of agricultural land exhibit a significant positive relationship in the long run, where the elasticity of land productivity in relation to public investment in agriculture is 0.55. Second, when controlling for endogenous structural breaks, the long-run equilibrium relationship for the productivity of the agricultural land model is still supported. Third, the results of the weak exogeneity test indicate that a causal relationship exists in the long run between public investment in agriculture and the productivity of land, indicating that the growth of the agricultural sector must in the long run be based on the government's public investment in the agricultural sector. Furthermore, as the agricultural sector grows, this growth is able to stimulate public investment on the part of the government in the agricultural sector, so that the two affect each other. Fourth, from the short-run error correction model estimation, it is found that public investment in agriculture is a major means of adjusting for the disequilibria that occur within the system. Fifth, in the short run, the unidirectional causal relationship in terms of the productivity of agricultural land on public investment in agriculture is established, otherwise it is not established. From this it can be seen that in the short run, the government is unable to reveal the effectiveness of its public investment in agriculture.

Jin and Miljkovic (2010) analyzed the movement of farm prices relative to other commodity prices for the period 1913:01 to 2003:12, and investigated the number and time of structural breaks and discussing likely causes of structural breaks in the relative farm prices. Bai and Perron's (1998, 2003) multiple structural change test with a dynamic programming algorithm was used. This test makes it possible to have an efficient computation of the estimates of the break points as global minimizers of the sum of squared residuals. They find six structural breaks when they consider only the mean process and two breaks when we consider the mean and autoregressive processes. Possible causes for these breaks are discussed.

Shahraki and Abbasian (2014) showed that energy consumption due to importance of energy in developing and promoting Human societies, role of energy demands at policies and decision making associated with production, distribution and supply as well as energy importance as an effective factor at agricultural production. According to new econometrics discussions, Presence or absence of structural breaks and regime change could effect on relationship between economic variables and ignoring it may lead to Misleading results, hence Presence of structural breaks and regime change at empirical relationship between energy consumption and value added growth is important at agricultural sector. So in this article, relationship between energy consumption and value added growth at agricultural sector have been studied using annual time series data on Iran's economy during (1967-2012) with emphasis on Structural break. In this regard, Zivot and Andrews Unit Root Test in endogenous from was used to determine structural changes and Gregory-Hansen co-integration test was used to determine long-term relationship between energy consumption and value added growth with emphasize on structural break. Finding showed that there was long-term relationship between energy consumption and value added growth at agricultural sector.

2.2.3 Empirical Literature Related to Structural Breaks in the Agricultural Sector in Indian Context

The literatures which deals with the empirical application related to the structural break analysis in agricultural sector in Indian context are also very few in number[2]. Some of them,

[2] The empirical application of structural break related to agricultural are also very few in number. Most of the studies related to structural break are found in other streams of economics. But those studies are not preview in this thesis. So I am skipping those studies in this chapter.

Mukhopadhyay and Sarkar(2001), Virmani (2005), Ghose and Pal (2007), Bhattacharyya and Bhattacharyya (2007), Sengupta, Ghosh and Pal (2009), Ghosh (2010), Chand and Parappurathu (2012), Pal and Ghose (2012), Ghose and Pal (2013), Ghosh (2013), Pal and Ghose (2013) and Kundu (2015) etc.

Mukhopadhyay and Sarkar(2001) used structural break of modern time series specification technique to test for acceleration in food grains production in West Bengal and found that there exists a negative effect on the level of food grains production in West Bengal, taking 1982-83 as break point. They also found that the underlying series is a Different Stationary (DS) series with drift implying that one cannot claim for the existence of a deterministic trend in the level of food grains production. However, their analysis is based on over all West Bengal economy. But West Bengal's agricultural production shows a great variability due to variability in land capacity, climate, fertilizer uses, irrigated area etc., from district to district. As a result one may not get a uniform growth rate for all the districts.

Virmani (2005) used growth regression analyses and introduce dummy for 1965-6 to 1979-80. Dummies with a starting year of 1963-4 etc were also tried. All these dummies turn out to be non-significant. Where other papers have suggested breaks in the seventies he found that dummy variables for potential breaks in 1971–72 and 1975–76 are however found to be even less significant. So, there are no statistically significant breaks in GDP growth from 1951-52 to 1979-80 once the 1980-81 breaks are accounted for. This result implies that any policy conclusions drawn on the basis of presumed slowdown in the sixties and/or seventies are likely to be wrong. Further, studies on the determinants of India's growth based on old data could be highly misleading from the current perspective. Only policy analysis for this period that takes account of the rainfall fluctuations and reduced rainfall during 1965-6 to 1979-80 will be credible.

Ghose and Pal (2007) measure inter-district disparity in growth of food grains production in West Bengal by applying both the exogenous and endogenous structural break analysis to test for acceleration in food grains production. In case of exogenous structural break analysis the impact of liberalization policies was analysed by taking 1991-92 as a break point. No evidence of either acceleration or deceleration in the level of food grains production is revealed after 1991-92 except for the district Malda and for Malda there is a positive break in the level of the series, statistically significant at 5% level is evident. In case of endogenous structural break the break point is not uniform; it varies across different district of West Bengal.

Bhattacharyya and Bhattacharyya (2007) analyzed the process of growth of the agrarian economy of West Bengal from 1980-81 to 2002-03. They found that there is a significantly negative trend break in 1992-93, which was the beginning of the liberalisation era in the Indian economy. The entire time period is divided into two sub-periods, namely, 1980-81 to 1991-92 and 1992-93 to 2002-03. They used the method of computing simple exponential growth rates, kinked exponential growth rates and log quadratic estimates. The former two methods suggest growth and trend breaks, but the latter shows the extent of instability. All eight variables related to the agrarian economy of West Bengal, namely, area, production, yield, consumption of fertiliser, proportion of hyv, cropping intensity, institutional credit and land reform show a decline in growth from the first to the second sub-period. All variables except area and land reform register significant deceleration. The trend break was particularly sharp for production, yield and fertiliser use.

Sengupta, Ghose and Pal (2009) considered the interstate variation of food grains, non food grains and total agricultural production by considering exogenous structural break due to Perron and endogenous structural break due to Zivot and Andrews.

Ghosh (2010) employed Zivot and Andrew's methodology on India's GDP agriculture data for the period 1960-61 to 2006-07 and identified 1988-89 and 1967-68 as two critical break dates.

Chand and Parappurathu (2012) analyzed the trends in agricultural productivity at the national and state levels and attempts to identify the major factors responsible for the varied performance of agriculture in different periods and in different states. The results of structural breaks suggests that trend growth rates for the seven phases corresponding to the six break points identified were worked out and were found to be 0.70%, 1.93%, 2.26%, 2.34%, 3.21%, 2.31% and 3.13% respectively for the periods 1960-61 to 1968-69, 1968-69 to 1975-76, 1975-76 to 1982-83, 1982-83 to 1988-89, 1988-89 to 1995-96, 1995-96 to 2004-05 and 2004-05 to 2010-11. As GDP agriculture grew more or less in the same fashion during the third and fourth phases with comparable trend growth rates, it was logically sound to treat them as a single phase. Consequently, for the overall GDP-agriculture series, six distinct phases of growth were chosen for further analysis:

(i) Phase I: Pre-green revolution period (PGR) – 1960-61 to 1968-69.

(ii) Phase II: Early green revolution period (EGR) – 1968-69 to 1975-76.

(iii) Phase III: Period of wider technology dissemination (WTD) – 1975-76 to 1988-89.

(iv) Phase IV: Period of diversification (DIV) – 1988-89 to 1995-96.

(v) Phase V: Post-reform period (PR) – 1995-96 to 2004-05.

(vi) Phase VI: Period of recovery (REC) – 2004-05 to 2010-11.2

The optimum number of breaks was determined on the basis of the Bayesian Information Criteria (BIC), a suitable indicator suggested by Bai and Perron (2003) and later found superior to other information criteria by Wang (2006). Accordingly, an optimum number of six breaks were selected, which also corresponds to minimum residual sum of squares (RSS).

Pal and Ghose (2012) test for the change in the level and or growth rate of the six major food crops namely Rice, Wheat, Maize (Corn), Jowar (Sorghum), Gram, Bajra and six cash crops like Cotton, Groundnut, Jute, Rapeseed/ Mastard Oil, Sugarcane and Tobacco produced in India for the period 1950-51 to 2009-10, using endogenous structural break test of modern time series approach, specifically attempt to test for improvement in the performance after the introduction of liberalization process. The distinguishing feature of the method is that the incorporation of the break point is not dependent on the prior belief of the researcher, rather is endogenously determined. From the verification of the statistical time series process it is possible to infer about the trend preserving properties highlighting whether the extent of the growth can be sustained or not and also about the degree of variability of the series. For some of the selected food crops like Jowar, Gram and cash crops like Cotton, Groundnut and Tobacco breakpoint occurs in the post liberalization period. Jowar and Cotton show breaks in both in level and growth, Gram confirms break only in the growth, while for Groundnut and Tobacco there exists break only in the level of the series, supporting the evidence of improved performance for these crops after the process of liberalization. All the cash crops and some food crops like Rice, Jowar and Bajra exhibit satisfactory performance showing trend preserving properties with constant variability and thus forming a convergent group. Wheat and Maize on the other hand follows stochastic trend, with the increase in variability is observed for Maize.

Ghose and Pal (2013) estimated and tested of structural break in the econometric time series models based on unit root to measure variation in the output of food grains, nonfood grains and total agricultural production for seventeen major states of India, over the period 1971-72 to 2008-09. Seventeen states are classified into four different regions namely East, West, North and South and conclusions are made regarding the performances of the different regions. This paper first of all estimates the break point of the respective series of output of food grains, nonfood grains and total agricultural production for 17 major states and find out whether the states are converging towards a stationary process having deterministic trend with respect to the above three types of output of agricultural sector. Secondly, the paper tested for the variation in the growth of these three types of output among different states and regions. The analysis suggests that rate of growth of food grains, nonfood grains and total agricultural production at all India level are 1.028, 1.241 and 1.162 respectively, confirming that the actual growth rate is well below 4% level as targeted by five year plans. A sufficient regional variation exists with respect to the nature of the growth process, the gap between the highest break point year and the lowest break point year of different states and the variability of agricultural output. In all the three types of output for most of the states, the break points year occur after 1991-92, the year when policies of liberalization was introduced in the Indian economy and the growth rate decreases after the break. However, positive thing to note is that the growth processes of the eight among the seventeen selected states and three out of four regions converge towards a positive deterministic trend forming a convergent group having constant variability of output overtime, showing on the whole more or less satisfactory performance of the agricultural sector over the entire period of analysis regarding the issue of convergence.

Ghosh (2013) had used Zivot and Andrew's model C to test for two breaks in the growth path of NSDPA in agriculture and food grains production in West Bengal by using the data from 1960-61 to 2009-10. He found that 1983-84 as the first break year for food grains production in

West Bengal with an upward shift in level and slope, and 1991-92 as the second break year with an upward shift in level but a downward shift in slope

Pal and Ghose (2013) applied a recent development in estimation and testing of structural break in the econometric time series model to measure inter-districts variation and to test existence of endogenous structural break in the level or growth rate in the output of food grains production in 13 districts of West -Bengal for the period 1960-61 to 2007-08, using Amit Sen's approach. West Bengal as a whole performed very well after the implementation of Panchayat System since 1982-83 but the performance of North Bengal is not satisfactory. In case of South Bengal there exists a strong inter-districts variation.

Kundu (2015) argued that **s**ome researchers have found an acceleration in the growth of agricultural production in West Bengal from the beginning of the 1980s, while other researchers have criticized the methodologies and findings of these studies and concluded that no significant acceleration in the production of food grains have occurred in West Bengal in the 1980s. In the present study, using modern time series techniques allowing for endogenous structural breaks in the growth path of the series under considerations, he had found the evidence of a statistically significant acceleration in the growth rate of productions of food grains, rice and aman rice in the 1980s, which was caused by a significant increase in the growth rate of yield of aman rice from 1980-81. However, this increase in the agricultural growth in West Bengal was rather short lived as the growth rate of yield of aman rice declined significantly in the state from 1986-87, which leads to a subsequent decline in the growth rate of production of foodgrains in the state from 1987-88.

2.2.4 Empirical Literature Related to Growth of Agricultural Sector not Involving Recent Development of Structural Break Analysis of Time Series Econometrics in International Context

There are huge numbers of studies associated with the problem of growth in the agricultural sector for international context. Among them Thurow et al., (1980), Kimball (1983), Stoneman and Ireland (1983), Zilberman (1985), Gardner's (1988), Lipton (1998), Haggblade and Hazell (1989), Matsuyama (1992), Lin (1992, Balisacan (1993), Cochrane (1993), Anderson, Pardey and Roseboom (1994), Zilberman et al.(1997), Evenson (2000), Irz, Lin, Thirtle and

Wiggins (2001), Kydd, Dorward, Morrison and Cadisch (2002), Dorward, Fan, Kydd, Lofgren, Morrison, Poulton, Rao, Smith, Tchale, Thorat, Urey and Wobst (2004), Pingali (2006), Mendola (2006), Poulton, Kydd and Dorward (2006), Gellrich, Baur, Koch and Zimmermann (2007), Chirwa, Kumwenda, Jumbe, Chilonda and Minde (2008), Dercon, Gilligan, Hoddinott and Woldehanna (2008), Lerman (2008), Thurlow (2008), Pauw and Thurlow (2010), Mabiso, Pauw and Benin (2012), Diaz-Bonilla, E., D. Orden and A. Kwieciński (2014) has been reported in this chapter.

Thurow et al., (1980) used the real option approach to assess how uncertainty and irreversibility considerations will affect adoption of free-stall dairy housing, a technology that increases productivity and reduces pollution. The source of uncertainty in their case is future environmental regulation. Using simulation techniques, they showed that expected annual returns, when investment is optimal under the real option approach, is more than twice the expected annual returns associated with adoption under the traditional net present value approach. Thus, the real value approach may lead to a significant delay in adoption of the free-stall housing and occurs when pollution regulations are very stiff.

Kimball (1983) stated that the probable effect of the increasing global atmospheric CO_2 concentration on agricultural yields was evaluated. More than 430 observations of the yield of 37 species grown with CO_2 enrichment were extracted from more than 70 reports published during the past 64 years. Most of the studies were performed in greenhouses or growth chambers. Open fields might respond less than greenhouses or growth chambers to increased CO_2 because nutrient levels in general world-wide agriculture are lower than those in the indoor studies, or open fields might respond more because light levels are generally higher outside. The data also were dominated by high value crops, but results should be applicable to the three-fourths of the world agriculture represented by the C_3 crops and possibly to the remaining C_4 crops as well. Keeping these limitations of the data in mind, the analysis showed that yields probably will increase by 33% (with a 99.9% confidence interval from 24 to 43%) with a doubling of atmospheric Cot concentration.

Stoneman and Ireland (1983) argued that firms producing the components of new technology recognize the dynamics of adoption and design their production and establish technology component prices accordingly, by taking advantage of the monopolistic power. So there is a clear correlation between the economics of innovation and adoption. An understanding of thee links is essential for design of better patent policy and public research strategies.

Zilberman (1985) introduced the dynamics of the threshold model of adoption that identified conditions under which the quasi-rents of farmers decline over time. His model did not take into account the changes in structure that may be associated with innovation agriculture. When innovations are embodied in technology packages that are both yield increasing (high-yield varieties) and laborsaving (tractors and other machineries) and agricultural demand is inelastic, then technological change will reduce quasi rent per acre and make operations in the farm sector less appealing to a large segment of the population. Thus the early adopters are likely to accumulate more of the land, increasing their farm size. Over time, structural change will result in a relatively small farm sector, and earnings per farm may actually increase as farms become much bigger.

Gardner's (1988) argued that the farm's population is now as well off or even better off than the nonfarm population in relative terms, especially in the United States. His findings are consistent with the process of technological change that led to accumulation of resources by small subgroups of farming populations, while at the same time the rest of the farm population migrated to the urban sector where earnings were better. But in addition to the gains from technological change, the adopters may also have benefited from a commodity program that overall slowed the decline in prices as well as the processes of globalization that may demand more elasticity over time.

Haggblade and Hazell (1989) argued that agricultural growth stimulates rural nonfarm activity by boosting demand for production inputs and consumer goods. But different kinds of agricultural technology promote different patterns of nonfarm linkages. To explore how key features of agricultural technology affect growth in the rural nonfarm economy, they reviewed an array of cross-section and time-series evidence bearing on the dynamics of the rural nonfarm economy. Then, using consumption and production parameters associated with different agricultural technologies, it introduces a simple model which isolates the effects of different technologies on nonfarm growth linkages.

Matsuyama (1992) examined the role of agricultural productivity in economic development is addressed in a two-sector model of endogenous growth in which (a) preferences are non homothetic and the income elasticity of demand for the agricultural good is less than unitary, and (b) the engine of growth is learning-by-doing in the manufacturing sector. For the closed economy case, the model predicts a positive link between agricultural productivity and economic growth, while, for the small open economy case, it predicts a negative link. This suggests that the openness of an economy should be an important factor when planning development strategy and predicting growth performance.

Lin (1992) employed province-level panel data to assess the contributions of de-collectivization, price adjustments, and other reforms to China's agricultural growth in the reform period. De-collectivization is found to improve total factor productivity and to account for about half of the output growth during 1978-1984. The adjustment in state procurement prices also contributed positively to output growth. Its impact came mainly from the responses in input use. The effect of other market-related reforms on productivity and output growth was very small. Reasons for slowdown in agricultural growth after 1984 are also analyzed.

Balisacan (1993) provided a critical look at the Philippines record with respect to agricultural growth and poverty alleviation. He argued that rapid agricultural growth, as demonstrated by the experience in the 1960s and 1970s, is not enough to pull the rural poor out of poverty as well as sustain rapid overall economic growth. Economic structures and the economic policy environment have to be conducive to the rapid growth of employment opportunities for the fast-growing labor force, particularly in the non agriculture sector

Cochrane (1993) divided the farming population into three subgroups— early adopters, followers and laggards. The early adopters may be a small fraction of the population and the impact of their adoption decision on aggregate supply and, thus, output prices are relatively small. Therefore, these individuals stand to profit from the innovation.

Anderson, Pardey and Roseboom (1994) argued that Growth in agriculture depends on many things but one of the most important is investment in agricultural research. Decision making in the agricultural research policy area can only be aided by access to better information. They overviewed a recent endeavor to move policy dialogue beyond merely qualitative impressions towards a process that is underpinned with new and cogent data. The data used have been assembled at ISNAR in a manner designed to make comparisons both over time and between countries more valid than has been the case in the past. The comparisons thus possible reveal considerable diversity both between countries and between broad regional aggregations. Also illuminated here are issues related to the commodity orientation, capital and labor intensity, and size and scope of particular national programs.

Zilberman et al.(1997) showed that adoption of irrigation technologies and, while adoption levels seemed to respond significantly to economic incentives, adoption did not occur in many of the circumstances when it was deemed to be optimal using the expected present value criteria. Much of the adoption occurs during drought periods when water prices escalate drastically. The option value approach provides a good explanation of the prevalence of adoption during crisis situations.

Lipton (1998) argued that outside sub-Saharan Africa (SSA) agricultural research (AR) yields excellent returns. Smallness (of countries and research stations), dispersion and high turnover make it hard to attain a “critical mass” of national AR scientists. To remedy this, they could concentrate on a few problems and crops - yet they have neglected many of the most important, i.g. cassava, and overstressed export crops. In other ways, too, European biases have distorted African AR. Socioeconomics, moreover, have entered research design too little and too late. Above all, current domestic funds have been too scanty and unreliable to adequately support international and capital-account AR efforts. This lack of steady commitment illustrates AR's need for direction from clearer agricultural policy - based on radically imposed information and recognizing SSA's dramatic rise in labor/land ratios. Guidelines for such policy are indicated: within these, a formalized and poverty-oriented AR design system is suggested.

Evenson (2000) argued that agricultural research and extension programs have been built in most of the world’s economies. A substantial number of economic impact studies evaluating the contributions of research and extension program to increased farm productivity and farm incomes and to consumer welfare have been undertaken in recent years. They reviewed these studies using estimated rates of return on investment to index economic impacts. In almost all categories of studies, median (social) estimated rates of return are high, (often exceeding 40 percent) but the range of estimates was also high. They concluded that most of the estimates were consistent with actual economic growth experiences.

Irz, Lin, Thirtle and Wiggins (2001) examined how important is agricultural growth to poverty reduction? This article first gave the theoretical reasons for expecting agricultural growth to reduce poverty. Several plausible and strong arguments applied – including the creation of jobs on the land, linkages from farming to the rest of the rural economy, and a decline in the real cost of food for the whole economy – but the degree of impact is in all cases qualified by particular circumstances. Hence, the article deploys a cross-country estimation of the links between agricultural yield per unit area and measures of poverty. This produces strong confirmation of the hypothesized linkages. It is unlikely that there are many other development interventions capable of reducing the numbers in poverty so effectively.

Kydd, Dorward, Morrison and Cadisch (2002) argued that there is widespread concern at continuing, and indeed deepening, poverty in sub-Saharan Africa, and the lack of processes of rapid and broad based economic growth to combat this. There is also debate about the role agriculture in driving pro-poor economic growth with some arguing that it has a critical role in this while others see it is as largely irrelevant. They examined these arguments. They summarized and critique what we term the Washington Consensus on Agriculture (a consensus that appears to be eroding) and alternative positions opposing investment in agriculture. They suggested that both sets of arguments pay insufficient attention to important institutional issues in development, and, having taken these into account, they concluded that agriculture has a critical role to play, largely by default as there are no other candidates with the same potential for supporting broad based pro-poor growth. However, there are immense challenges to agricultural growth, challenges that in some cases may be too great to be economically viable. In considering economic viability, however, regard must be taken of the economic and social costs of rural stagnation and of providing safety nets in situations of enduring poverty. Policy needs to focus more on agriculture, and recognize and address the diversity of institutional, trade, technological and governance challenges to poverty reducing growth in Africa.

Dorward, Fan, Kydd, Lofgren, Morrison, Poulton, Rao, Smith, Tchale, Thorat, Urey and Wobst (2004) stated Global experience with pro-poor growth and empirical work spanning India, Malawi and Zimbabwe demonstrates the importance of agricultural growth for poverty reduction in poor rural areas, while also pointing to the need for complementary non-farm sector growth. Theoretical arguments, historical evidence and livelihoods modeling in poor medium-potential rural economies suggest that, contrary to thinking dominating much of current development policy, subsidies to relieve critical seasonal credit and cash restraints and reduce market and input supply uncertainties need to help in ‘kick-starting’ agricultural markets if increased smallholder productivity in food-grains is to drive rural non-farm growth. Establishing the base conditions for these to work, designing and implementing them to be effective, and then phasing them out are major challenges facing policymakers.

Pingali (2006) re-investigated the age old proposition that agriculture growth contributes to overall economic development, and asks whether the relationship still holds in an increasingly globalized world. There is overwhelming empirical support for the above proposition, indeed, it is hard to find exceptions, barring a few city states, where sustained economic development has not been preceded by robust agricultural growth. However, there are a large number of countries that have witnessed neither agricultural growth nor economic development. Even in countries where agricultural growth has been significant, dramatic inter-regional differences persist. This paper examined the factors that contribute to or constrain the process of agricultural transformation. Does the process of globalization, and the resultant changes in agrifood systems, offer new opportunities for agriculture led growth, or will it further marginalize excluded countries, regions and groups? The factors that cause exclusion are examined both in terms of globalization forces and in terms of domestic shortcomings in policies and governance. Policy interventions that attempt to reduce the costs of transition to a globalized agricultural system are explored, including safety nets for those left behind.

Mendola (2006) aimed at shedding some light on the potential impact of agricultural technology adoption on poverty alleviation strategies. It does so through an empirical investigation of the relationship between technological change, of the Green Revolution type, and wellbeing of smallholder farm households in two rural Bangladeshi regions. As technology adoption is not randomly assigned but there is ‘self-selection into treatment’, he tackled a methodological issue in assessing the causal effect of technology on farm-household wellbeing through the non-parametric‘p-score matching analyses. It pursues a targeted evaluation of whether adopting a modern seed technology causes resource-poor farmers to improve their income and decrease the propensity to fall below the poverty line. It finds a robust and positive effect of agricultural technology adoption on farm household wellbeing suggesting that there is a large scope for enhancing the role of agricultural technology in 'directly' contributing to poverty alleviation.

Poulton, Kydd and Dorward (2006) argued that in sub-Saharan Africa, there is fairly broad agreement that increased investment in key public goods such as roads and communications infrastructure, agricultural research and water control will be required if revitalized agricultural development is to take place. However, it has proved more difficult to reach agreement on what needs to be done to improve the performance of agricultural markets. In this article they set out an agenda for investment and policy reform in this area, providing a brief theoretical examination of the co-ordination problems involved before examining in turn demand and supply constraints affecting smallholder farmers, and policies for price stabilization and the co-ordination of support services. We also argue that increased attention needs to be paid to governance issues.

Gellrich, Baur, Koch and Zimmermann (2007) stated that natural forest re-growth reflects a decline in traditional agricultural practices that can be observed worldwide. Over the last few decades, natural forest re-growth has replaced much of the agricultural land in the Swiss mountains. This is a region where forms of traditional cultivation have preserved unique landscapes and habitats of high ecological value. They aimed to characterize the locations in the Swiss mountains where agricultural land has been abandoned and overgrown by trees and bushes. Therefore, multivariate statistical models based on geo-physical and socio-economic variables were developed. Land-use change data were taken from two nationwide land-use surveys carried out in the 1980s and 1990s. In order to obtain reliable models, neighbourhood effects and the group structure in our data were accounted for. For the latter a robust estimation technique known as cluster-adjustment was used. Results show that forest re-growth is largely restricted to former alpine pastures, land with grass and scrub vegetation and agricultural land with groups of trees at mid to high altitudes, steep slopes, stony ground and a low temperature sum. Some relationships were not as expected, e.g. many of the new forest areas were found to be relatively close to roads. A new finding from this study was that forest re-growth is largely restricted to regions with immigration, higher proportions of part-time farms as opposed to full-time farms and high farm abandonment rates. By accounting for neighbourhood effects, the model fit was improved. The considerable residual deviance of the models was interpreted as the result of undetected local characteristics, such as poor water availability, small-scaled topographic peculiarities (e.g. small trenches, stonewalls, soil damages by cattle) and the individual's motivation to abandon or maintain cultivation. The conclusion made was that general policy measures for the whole mountain area are not suitable for the prevention of land abandonment and forest re-growth, and that policy measures must pay more attention to local characteristics and needs.

Chirwa, Kumwenda, Jumbe, Chilonda and Minde (2008) reviewed the link between agricultural growth and poverty reduction in Malawi. The contribution of the agriculture sector in Malawi has been fairly stable over time, accounting for more than one-third of gross domestic product. However, the performance has been mixed in terms of growth rates, with more growth witnessed in the 1960s and 1970s and erratic growth rates in subsequent periods. The analysis also showed no significant link between the growth in the agricultural sector and indicators of poverty such as malnutrition rates and poverty head count ratio. The disappointing performance of the agriculture sector can be attributed to many factors including declining farm productivity, rain-fed nature of cultivation and associated exogenous shocks, thin agricultural markets, policy reversals and associated uncertainties, and declining public investments in the agricultural sector. In order to revive the agricultural sector, the study recommends policies towards greater commercialization, revitalization of extension services and increased investments in marketing systems, rural infrastructure and irrigation development.

Dercon, Gilligan, Hoddinott and Woldehanna (2008) investigated whether public investments that led to improvements in road quality and increased access to agricultural extension services led to faster consumption growth and lower rates of poverty in rural Ethiopia. Estimating an instrumental variables model using Generalized Methods of Moments and controlling for household fixed effects, they found evidence of positive impacts with meaningful magnitudes. Receiving at least one extension visit reduces headcount poverty by 9.8 percentage points and increases consumption growth by 7.1 percent. Access to all-weather roads reduces poverty by 6.9 percentage points and increases consumption growth by 16.3 percent. These results are robust to changes in model specification and estimation methods.

Lerman (2008) used long time series of basic agricultural statistics in 12 countries of the former Soviet Union, this article explores the changes in resource use, agricultural production and productivity during the transition. While the share of labour employed in agriculture has increased in all the countries analyzed, the share of agriculture in GDP has declined, pointing to generally decreasing productivity of agriculture relative to manufacturing and other sectors of the economy. The precipitous transition decline that began in 1991 with the break-up of the Soviet system gave way to definite recovery starting around 1998. Agricultural growth and performance are shown to be positively linked with individualization of farming in transition countries and with various measures of policy reform. Countries that have achieved greater progress in the implementation of agricultural reform record better agricultural performance

Thurlow (2008) analyzed agricultural growth options that can support the development of a more comprehensive rural development component under Mozambique's revised agricultural strategy that is also in alignment with the principles and objectives collectively defined by African countries as part of the broader NEPAD agenda. In particular, they tried to find to position Mozambique's agricultural sector and rural economy within the country's national strategy. For these purposes, and to assist policymakers and other stakeholders to make informed long-term decisions, an economy-wide, computable general equilibrium (CGE) model for Mozambique has been developed and used to analyze the linkages and trade-offs between economic growth and poverty reduction at both macro- and micro-economic levels.

Pauw and Thurlow (2010) stated that rapid economic growth has failed to significantly improve poverty and nutrition outcomes in Tanzania. This raises concerns over a decoupling of growth, poverty, and nutrition. They link recent production trends to household incomes using a regionalized, dynamic computable general equilibrium and microsimulation model. Results indicate that the structure of economic growth—not the level—is currently constraining the rate of poverty reduction in Tanzania. Most importantly, agricultural growth trends have been driven by larger-scale farmers and by crops grown in only a few regions of the country. The slow expansion of food crops and livestock also explains the weak relationship between agricultural growth and nutrition outcomes. Additional model simulations find that accelerating agricultural growth, particularly in maize, greatly strengthens the growth–poverty relationship and enhances households' caloric availability. They conclude that low productivity, market constraints (including downstream agroprocessing), and barriers to import substitution for major food crops are among the more binding constraints to reducing poverty and improving nutrition in Tanzania.

Mabiso, Pauw and Benin (2012) argued that Kenya's Medium Term Investment Plan (MTIP) outlines the government's investment strategy for achieving the goals of the Agricultural Sectoral Development Strategy (ASDS), which are in alignment with the Comprehensive African Agricultural Development Programme (CAADP). In implementing the plan, the government seeks to prioritize investments across the country's three major agro-economic zones (AEZ). They commissioned to analyze growth and investment options across the three AEZ, revised and updated Kenya's Social Accounting Matrix (SAM) so that productive activities and households are disaggregated by AEZ. Following the SAM revision, Computable General Equilibrium (CGE) model simulations were performed to identify priority subsectors and commodities within each AEZ. The simulations were based on criteria jointly established by a task team and stakeholders during expert panel sessions, taking into account the relative importance (weighting) of regional versus national poverty or of different subsector-led growth scenarios. Past public expenditures in each AEZ were then analyzed together with planned regional investments, as delineated in the MTIP, thus indicating potential outcomes that may arise from the proposed regionalized investments. Results of the CGE analysis suggested that for Kenya to achieve the CAADP goal of 6 percent agriculture GDP growth rate, subsector growth would have to increase significantly across the board, with maize, other roots, pulses, fruits and tea each requiring growth rates greater than 6 percent. Export crops would also have to perform exceedingly well, growing at 6.2 percent. Results also showed that in the CAADP scenario, national poverty declines to 24 percent, which represents an additional 4.2 percentage-point poverty reduction between 2010 and 2020 as compared to the baseline scenario. Households in high-rainfall areas would benefit the most from the CAADP investment scenario compared to the baseline, in relative terms, and see their poverty rate slashed by slightly more than half to 15.3 percent. Poverty in the arid areas would drop to 50.2 percent, which in relative terms is the smallest reduction in poverty—although in absolute terms the reduction is similar to that in semi-arid areas, where a 20 percentage point poverty reduction is observed. The review of the MTIP by AEZ shows that it rightly dedicates more to the semi-arid areas, particularly for irrigation and roads infrastructure as well as value chain developments. This is in line with the CGE results and previous studies, which show that Kenya can significantly reduce national poverty if more investments are directed to semi-arid areas' irrigation and road infrastructure. The allocation of investments by subsector is however not discussed in the MTIP; ensuring adequate investments in maize and root crops in the semi-arid and high rainfall areas would be important. Also, increasing investments in traditional exports in the high rainfall areas would be critical for agricultural growth though having less effect at reducing national poverty due to weaker economy wide linkages (multiplier effects). Investments in the arid areas are also important, particularly in terms of livestock and enhancing resilience to drought. However, given its smaller population and weaker linkages to the rest of the economy, investments in the arid areas are least effective at reducing national poverty. Therefore, finding ways of enhancing these linkages and of crowding in private sector investments as well as coordinating public investments at the regional level across countries could create significant synergies. Likewise, linking public investments across sectors within government and with the private sector could enhance synergies and is worth considering for the future.

Diaz-Bonilla, E., D. Orden and A. Kwieciński (2014) developed a typology to structure the components of the enabling environment for agricultural growth and competitiveness, and in constructing an illustrative Agricultural Growth Enabling Index (AGEI) to summarize a wide array of available information in a coherent manner. The construction of the preliminary AGEI is based on four blocks with 40% of the weight on agriculture/rural factors and 20% each on broader economy-wide governance, capital availability and market operation. The AGEI can be used to provide a cross-country comparisons or single-country evaluations using the index itself or its components. It allows the decomposition within each main block to show the relative strength and weaknesses of each country across various sub-indices. It has been applied here to a selected set of twenty emerging and developing countries. The preliminary results demonstrate that the AGEI brings together information relevant to the enabling environment for agricultural growth and competitiveness, and which is largely consistent with more in-depth studies of the selected countries. While constrained in some respects, the AGEI appears to be the first index completed with this objective. Further expansion and refinement of the included set of indicators to better reflect key determinants of agriculture's enabling environment would help provide an important input into better policy decisions.

2.2.5 Empirical Literature Related to Growth of Agricultural Sector not Involving Recent Development of Structural Break Analysis of Time Series Econometrics in Indian Context

There are several studies that examined the growth performance of Indian Agricultural Sector. Some of the important studies are done by Ahluwalia (1977), Bergmann (1984), Rao and Deshpande (1986), Boyce (1987), Kohli (1987), CMIE (1993), Chattopadhyay et al. (1993), Saha and Swaminathan (1994), Sen and Sengupta (1995), Banerjee and Ghatak (1996), Roychaudhuri and Sen (1996), Saha (1996), Bhalla and singh (1997), Rawal and Swaminathan (1998), Harris, Joshi, Khan, Gothkar, and Sodhi (1999), Chattopadhyay and Das (2000) , Banerjee, Gertler and Ghatak (2002), Fan (2002), Bajpai and Volavka (2005), Mall, Singh, Gupta, Srinivasan and Rathore (2006), Bardhan and Mookherjee (2007), Deininger, Jin and Nagarajan (2007), Ghatak and Roy (2007), Bosworth and Collins (2008), Deininger, Jin and Yadav (2008), Bhalla and Singh (2009), Kalamkar (2009), Biswas (2010), Kannan and Sundaram (2011), Mani, Bhalachandran and Pandit (2011), Sharma (2012), Asha latha K. V., Gopinath, and Bhat (2012), Ghosal (2012), Raman and Kumari (2012), Sengupta and Sonwani (2012), Birthal, Joshi, Negi and Agarwal (2013), Kaur (2013), Salam, Anwer and Alam (2013), Behera (2014), Lone (2014), Ramachandra, Anand and Manjuprasad (2014), Kaur (2015) among others.

Ahluwalia (1977) examined time series evidence on rural poverty over the past two decades. The results showed that the incidence of poverty fluctuates in response to variations in real agricultural output per head, but there is no significant time trend. There is a statistically significant inverse relationship between rural poverty and agricultural performance for India as a whole, suggesting that agricultural growth by itself tends to reduce the incidence of poverty. The analysis for individual states presents a somewhat different picture. The inverse relationship between output per head and rural poverty is observed in several states but there is also evidence that there are processes at work which tend to increase the incidences of poverty, independently variation in agricultural output per head.

Bergmann (1984) in his case study in a village named Nowasan in 24-Paraganas in February 1982 found that a bitter relation had emerged between the landlord and the bargadars. The relation deteriorated to such an extent that murder of a bargadar by the landlord had occurred. From this it is evident that mutual help between the landowner and bargadar had ceased to operate. Moreover, it is very much possible that the landowner will shop all such credit facilities like production advance and consumption loan to the bargadars.

Rao and Deshpande (1986) argued that **w**hile the agricultural sector has witnessed some startling breakthroughs, doubts are now being expressed whether the growth is fast enough and sustained enough to carry the economy through the next few critical decades. They examined the shifts in the sources of growth since the sixties from area increase to improvements in yields; growth in irrigation and in the use of modern inputs; and take a brief look at the recent changes in the agriculture's terms of trade. Against this background the authors pose the complex question of the relationship between agricultural growth and the welfare of the rural masses and identify three major frontiers which need to be crossed to push agricultural growth beyond its present limits.

Boyce (1987) estimated the growth rate of agricultural output "between" 1949 to 1980 was only 1.74% per annum. At the root of agricultural stagnation was limited growth in the production of "aman" rice, the most important crop of West Bengal. Whatever the agricultural growth of output occurred during this period was mainly a result of secondary crops like Aus and Boro rice, Jute, Wheat, and Potato. While the decade of 1970's was marked by stagnation in the agricultural performance in eastern India, an important change occurred in 1980's. Between 1981 and 1991 rates of growth of agricultural production in the eastern India increased and among them the growth of agriculture in West Bengal is fastest.

Kohli (1987) had surveyed 300 registered sharecroppers in July to September 1993. The main conclusions of the study are the following :(i) Majority among those who have lost control of their lands-nearly 80 per cent - were absentee landlords. Those gaining control in turn are largely small and marginal peasants. Out of them, those owning less then I acre of own land are 85 per cent of the total. Operation barga has hurt absentee landowners while benefiting, the insecure share-croppers, (ii) Crop share of the bargaders had increased sine registration for nearly 70 per cent of the cases.(iii) Majority of the sharecroppers were not receiving any inputs from the landowners even prior to registration. The reason of the non-participation is the fact that as many as 80 per cent of the landowners in the sample were absentee. So Kholi concluded that it is not likely that the breakdown in the old nexus of goodwill between the landowners and the bargaders will have disruptive consequences for either the personal welfare of the sharecropper or agriculture production in general.

CMIE (1993) also suggested that between 1980-81 and 1992-93 the rate of growth of food grains production in West Bengal was highest of 17 major states of India.

Chattopadhyay et al. (1993) who found no statistical evidence in support of break in total food grains production in West Bengal during the period 1950-51 to 1987-88 in all states in eastern region barring Orissa. They fitted three types of trend curves viz., straight line, semi-log and Gompertz, and inferred on the basis of the fitted curves that there had not been any acceleration in the growth of agriculture in all the three states in Eastern India except Orissa, primarily because of diminished/constant rate of growth of cropped area under the major crops in this region.

Saha and **Swaminathan (1994)** analyzed the data on agricultural production in the state West Bengal by districts wise and crop wise and for rice seasons wise and compare their estimated results with that of period up to 1980. In this study they studied what they called "changing trajectories" of agricultural growth in West Bengal. In that paper the authors considered two deterministic trends function viz., exponential and log-quadratic, and estimated these using time series data on total food grains production in West Bengal spanning the period 1965 to 1990, and finally concluded that West Bengal experience accelerated growth in agriculture during the eighties. They attributed this performance to the implementation of land reforms and establishment of Panchayati Raj system (i.e., decentralized administration at the local level) in the state.They also found the support of acceleration of agricultural output in West Bengal.

To identify the effects of tenancy reform on aspects of production, **Ghatak (1995)** used districts level panel data to identify the direction of correlation between the extents of recorded bargadars. He found that (i) operation barga has a positive lag effect on output,(ii) operation barga has significant positive effect on the rate of expansion of boro cultivation and on investment on private irrigation, (iii) public has a positive effect on production.

Sen and Sengupta (1995) in a study of West Bengal, Orissa and Bihar found a trend break in the rate of growth of total production of rice and of yield per hectare of rice and food grains in the three states in 1981-82.the growth rates of net value added in agriculture at constant price in West Bengal was 6.85% in the 1980's as compared to 2.3% in the 1970's. They also found that a structural break exist in the series on agricultural output even when the series was adjusted for growth in inputs.

Banerjee and Ghatak (1996) also estimated the contribution of tenancy reforms to the overall growth of output and found it to be as high as 36% for all rice production and 72% for aman rice production.

Roychaudhuri and Sen (1996) tried to find out the effect of operation barga on land productivity. The method applied to estimate the production function to compare the productivity of land to different degrees of recording. They have estimated o regression equation where productivity per acre of crop is explained as a function of rainfall, percentage of net irrigated land to total land for marginal/small farmers, labour used per acre (both hired+family), per acre fertilizer use of the districts and the dummy variable which measures the effect of operation barga between the low recorded districts and high recorded districts. The results of estimation suggest that the effect of operation barga has a negative effect on the productivity per acre on aman. The implication of this result is that due to operation barga there is a fall in the per unit productivity of aman paddy in West Bengal. The other significant variables are labour per acre and fertilizer use. The most important variable explaining productivity per acre of crop is the fertilizer use.

Saha (1996) examined the time path f the diffusion process of high yielding variety (HYV) seeds in West Bengal and a few other rice producing states namely Orissa, Bihar, Andra Pradesh, Punjab, Uttar Pradesh, and Tamil Nadu, for the period 1966 to 1999.He also examined the impact of HYV seeds and fertilizer use on rice yield in West Bengal, Bihar, and Orissa. It is found that the eighties marked a significant improvement in yield elasticties with respect to fertilizer and HYV coverage in all the three states-West Bengal, Bihar, and Orissa. Increases in elasticity with respect to both these inputs, however has been most pronounced in west Bengal than Bihar and Orissa. The variation of yield impact of new technology across these states and over time is examined the determinants of the process of adoption of seeds fertilizer water technology in West Bengal. In particular the role of fertilizer, irrigation, and other infer structure on output adoption of HYV and input application. The empirical exercise suggests that the degree of adoption of HYV rice, crucially depends on the availability of irrigation and other infers rural facilities. Also while there has been a significant improvement in the utilization of new rice technology in West Bengal during the eighties, the key of the success has been revitalization of the small farmers. Examination of the cross section data in the mid eighties suggest that small farmers have catching their large counter parts. Not only there exist no evidence of difference in the level of yield between farmers of different size, application of fertilizer and cash component per unit of land also do not bear any relation to the size of the farm.

Bhalla and Singh (1997) also analyzed the agricultural growth experienced by the eastern region in general and West Bengal in particular, and found evidence of agriculture growth, the occurrence of which was explain by them in pioneering study on the agricultural performance in West Bengal during the period 1949 to 1980, (Boyce (1987)) found, by using kinked exponential form, evidence of a modest positive “trend break” in the rate of growth of agriculture from mid-1960s.

Rawal and Swaminathan (1998) also studied the growth performance in agriculture in West Bengal in general and also for 15 districts in West Bengal for the period 1950-95. To check the contribution of weather conditions on the high growth of output they also estimated districts wise growth rate with an adjustment for rainfall for the period 1980-95. The rainfall index is defined as the percentage of actual rainfall to normal rainfall. Their analysis suggests that compound growth rate of food grains production from 1950 to 195-95 was .56% as compared to 4.56% between 1980 to 1985. They also summarize the available evidence on the impact of changes in agricultural relations on agricultural performance. Specifically they discussed the impact of operation barga. Further they also discussed other features of agricultural developments in 1980’s like the seeds and fertilizer use, use of irrigation facilities and also about credit and marketing.

Harris, Joshi, Khan, Gothkar, and Sodhi (1999) identified poor crop establishment as a major constraint on rainfed crop production by farmers in the tribal villages of Rajasthan, Gujarat and Madhya Pradesh served by the Krishak Bharati Cooperative (KRIBHCO) Indo-British Rainfed Farming Project (KRIBP). On-farm seed priming with water was chosen as a low cost, low risk intervention appropriate to the farmers' needs. In vitro screening of the effects of priming on the germination of seeds of local and improved varieties of maize, upland rice and chickpea provided `safe limits' - the maximum length of time for which farmers should prime seeds and which, if exceeded, could lead to seed or seedling damage. Recommended safe limits were 24 h for maize and rice and 10 h for chickpea, with only minor varietal differences. These recommendations were then tested in on-station trials in Dahod, Gujarat. Farmer-managed trials were conducted for chickpea in three villages in the rabi (post-monsoon) season in 1995-96; for maize and upland rice in eight villages in the kharif (monsoon) season in 1996; and for maize and chickpea in 15 villages in the 1996-97 rabi season. Farmers modified these recommendations to `overnight' for all three crops. Evaluation of the technology by farmers involved focus group discussions, matrix ranking exercises and two workshops. Direct benefits in all three crops included faster emergence, better stands and a lower incidence of re-sowing, more vigorous plants, better drought tolerance, earlier flowering, earlier harvest and higher grain yield. Indirect benefits reported were earlier sowing of rabi crops because of the shorter duration of the preceding kharif crop, earlier harvesting of rabi crops that allowed earlier migration from the area, with better chance of obtaining off-season work, and increased willingness to use fertilizers because of reduced risk of crop failure. In matrix ranking exercises in four villages in the kharif 1996, 95% of farmers indicated that, even after only one exposure to the technology, they would prime seed in the following season. Similar exercises in four villages in rabi 1996-97 revealed that 100% of collaborating farmers intended to continue seed priming. From 21 villages, 246 farmers attended two workshops to share their experiences of seed priming and resolved to continue with the technology.

Chattopadhyay and Das (2000) estimated a generalized kinked and exponential model for the period 1957-58 to 1994-95. With two sub period (i) 1957-58 to 1976-77 (ii) 1977-78 to 1994-95, using district level data and found that the rate of growth of agricultural production in West Bengal during the Left Front rule has been certainly higher than the during the pre Left

Front rule. And only a few have dominated the field of farmers by elbowing out other crops, like high protein pulses, wheat etc.

Banerjee, Gertler and Ghatak (2002) analyzed the effect of agricultural tenancy laws offering security of tenure to tenants and regulating the share of output that is paid as rent on farm productivity. They argued that theoretically, the net impact of tenancy reform is shown to be a combination of two effects: a bargaining power effect and a security of tenure effect. Analysis of evidence on how contracts and productivity changed after a tenancy reform program was implemented in the Indian state of West Bengal in the late 1970s suggests that tenancy reform had a positive effect on agricultural productivity there.

Fan (2002) analyzed the impact of agricultural research on urban poverty reduction in India by considering State level data from 1970 to 1995. It is found that in addition to its large impact on rural poverty reduction, agricultural research investments have also played a major role in the reduction of urban poverty. Agricultural research investments increase agricultural production, and increased production in turn lowers food prices. The urban poor often benefit proportionately more than the non-poor since they spend 50-80% of their income on food. Among all the rural investments considered in this study, agricultural research has the largest impact on urban poverty reduction per additional unit of investment. Today, urban poverty still accounts for one quarter of total poverty in India, and this share is expected to rise in the future. Policymakers cannot afford to be complacent about this trend and continued investments are still needed to keep food prices low. Among all government policy instruments, increased agricultural research is still the most effective way to achieve this objective.

Bajpai and Volavka (2005) attempted to identify and analyze the issues and problems associated with the agriculture sector of India's most populous state, Uttar Pradesh (U.P.). They begin with the pre-Green Revolution period, from the early 1960s and examine the growth of agricultural outputs springing from the Green Revolution in U.P. and those in relation to Punjab and Haryana, India's most successful states as far as the agriculture sector is concerned. Additionally, we study of the growth of agricultural inputs in U.P overtime to consider intrastate variations in patterns of agricultural development between western and eastern U.P. In order for U.P. to be able to attain and sustain higher levels of growth in its agriculture and allied sectors, the following areas will require much higher public investments and the state government's attention: increased focus on irrigation; increased expenditure in agricultural research and development; capacity expansion in U.P.'s agricultural universities; diversification of crops; revamping of the agricultural extension system to assist farmers in adopting new technologies; building up rural infrastructure, and promotion of agro-based industries.

Mall, Singh, Gupta, Srinivasan and Rathore (2006) stated that during the recent decade, with the growing recognition of the possibility of climate change and clear evidence of observed changes in climate during 20th century, an increasing emphasis on food security and its regional impacts has come to forefront of the scientific community. In recent times, the crop simulation models have been used extensively to study the impact of climate change on agricultural production and food security. The output provided by the simulation models can be used to make appropriate crop management decisions and to provide farmers and others with alternative options for their farming system. It is expected that in the coming decades with the increased use of computers, the use of simulation models by farmers and professionals as well as policy and decision makers will increase. In India, substantial work has been done in last decade aimed at understanding the nature and magnitude of change in yield of different crops due to projected climate change. They presented an overview of the state of the knowledge of possible effect of the climate variability and change on food grain production in India.

Bardhan and Mookherjee (2007) used a disaggregated farm panel, controlling for other land reforms, agriculture input supply services, infrastructure spending of local governments, and potential endogeneity of land reform implementation. They found a significant positive effects of lagged village tenancy registration rates. But the direct effects on tenant farms are overshadowed by spillover effects on non-tenant farms. The effects of tenancy reform are also dominated by those of input supply programs and irrigation expenditures of local governments. These results indicate the effects of the tenancy reform cannot be interpreted as reduction of Marshall-Mill sharecropping distortions alone; village-wide impacts of land reforms and agricultural input supply programs administered by local governments deserve greater attention.

Deininger, Jin and Nagarajan (2007) argued that recognition of the importance of institutions that provide security of property rights and relatively equal access to economic resources to a broad cross-section of society has renewed interest in the potential of asset redistribution, including land reforms. Empirical analysis of the impact of such policies is, however, scant and often contradictory. This paper uses panel household data from India, together with state-level variation in the implementation of land reform, to address some of the deficiencies of earlier studies. The results suggest that land reform had a significant and positive impact on income growth and accumulation of human and physical capital. The paper draws policy implications, especially from the fact that the observed impact of land reform seems to have declined over time.

Ghatak and Roy (2007) did an empirical literature on the impact of land reform on agricultural productivity in India. They found that, overall for all states; land-reform legislation had a negative and significant effect on agricultural productivity. However, this hides considerable variation across types of land reform, as well as variation across states. Decomposing by type of land reform, the main driver for this negative effect seems to be land-ceiling legislation. In contrast, the effect of tenancy reform, averaged across all states, is insignificant. There seems to be a wide range of state-specific effects, which suggests that focusing on average treatment effects can hide a considerable amount of heterogeneity. In particular, allowing a separate slope for West Bengal, one of the few states that implemented tenancy laws rigorously, they found that land reform had a marginal positive effect relative to the rest of India.

Bosworth and Collins (2008) examined sources of economic growth in China and India, comparing and contrasting their experiences over the past 25 years. They argued that in many respects, China and India seem similar. Both are large geographically and have enormous populations that remain very poor. In 1980, both had extremely low per capita incomes. Since 1980, both countries have sustained impressively rapid growth. However, many details of their economic growth experiences are in fact quite different. In this paper, they investigated patterns of economic growth for China and India by constructing growth accounts that uncover the supply-side sources of output change for each economy. Some of the results confirm themes that have emerged from the prior literature on the economic development of the two countries. For example, China stands out for the explosive growth in its industrial sector, which in turn was fueled by China’s willingness to act more quickly and aggressively to lower its trade barriers and to attract foreign direct investment inflows. In contrast, India's growth has been fueled primarily by rapid expansion of service-producing industries, not the more traditional development path that begins with an emphasis on low-wage manufacturing. However, some new findings emerge as well. The decompositions of aggregate output growth enable us to compare experiences in these countries to one another as well as to experiences of other economies. In addition, they construct separate accounts for the three major economic sectors: 1) agriculture (which also includes forestry and fisheries); 2) industry (manufacturing, mining, construction, and utilities); and 3) services. (In the literature, these sectors are often referred to as primary, secondary, and tertiary, but they will stick to these more descriptive terms in this paper.) This level of detail enables them to highlight key differences in the development paths taken by China and India. It also enables us to assess the efficiency gains associated with the movement of workers out of agriculture, where they are frequently under-employed, into higher productivity jobs in industry and services.

Deininger, Jin and Yadav (2008) argued that land reform has been the subject of considerable scholarly debate, most of the analyses have been at the aggregate level and focused on rather short-term effects. We use a listing of more than 90,000 households in some 200 villages in West Bengal to highlight the impact of the state's 1978 land reform program on human capital accumulation and current productivity of land use. While we ascertain a highly significant positive effect on long-term accumulation of human capital, our analysis also suggests that, partly because land that had been received through land reform is still operated under share tenancy arrangements, productivity on such land is significantly lower than the average. The combination of lower productivity of reform land relative to own land and land rental and sale's restriction of reform land is associated with significantly lower purchase and sale's price of reform land compared to own land. Programs to allow land reform beneficiaries to acquire full ownership could thus have significant benefits.

Bhalla and Singh (2009) analyzed the performance of agriculture at the state level in India during the post-reform period (1990-93 to 2003-06) and the immediate pre-reform period (1980-83 to 1990-93) shows that the post-reform period has been characterized by deceleration in the growth rate of crop yields as well as total agricultural output in most states. By ending discrimination against tradable agriculture, economic reforms were expected to improve the terms of trade in favour of agriculture and promote its growth. The paper also discusses the cropping pattern changes that have taken place in area allocation as well as in terms of value of output. The slowdown in the process of cropping pattern change means that most government efforts to diversify agriculture have failed to take off.

Kalamkar (2009) attempted to analyze the relationship between urbanisation and agricultural growth in India. He argued that the processes of urbanization and economic development will be irreversible and hence how agricultural production will respond to such changes needs to be analyzed. He stated that Indian agriculture has witnessed significant variations over the last five decades; there were phases of significant growth and stagnation. But over years, the country has emerged out of the state of chronic hunger and abject dependence on the import, to achieve self sufficiency in availability of food grains. Particularly, this was achieved even under the increasing pressure of population growth at a significant rate. The population growth has resulted in a downward trend in per capita availability of forest and agricultural land since the 1950s. Also, the per capita availability of food grains has fallen substantially during the last decade of reforms, and the maximum decline has taken place during the last five years. The faster growth in urban population is largely on account of migration from rural areas. Exchanges of goods between urban and rural areas are an essential element of rural-urban linkages. Urbanisation is an important determinant of demand for high value commodities. By 2020, urban population is expected to be nearly 35 per cent of the total population. This is expected to fuel rapid growth in the demand for high value food commodities. There is a need to control poverty and population growth below replacement level in the country and unless significant measures are taken to incorporate environmental concerns into agricultural development, urban planning, technological innovations, industrial growth, and resource management, the situation is likely to worsen in the future.

Biswas (2010) argued that Volumes have been written about agriculture in India, but the success stories of farmers are rarely written. Realizing the importance of farmers in agriculture, of late, National Policy for Farmers (NPF, 2007) has been framed. But how far the Policy initiatives taken so far have benefited the farmers has to be critically analyzed. Wide gap exists between the theory and practice in Indian Agriculture. Theoretically our documents are well written, but our theories are rarely practiced at user level. In this paper, an attempt has been made to high light the policy initiatives and the success story of a U.P. farmer.

Kannan and Sundaram (2011) discussed the trends and patterns in agricultural growth at the national and sub-national levels in India. Data on important variables like area, production, input use and value of output were compiled for the period 1967-68 to 2007-08 from various published sources. The analysis of data reveals that the cropping pattern in India has undergone significant changes over time. There is a marked shift from the cultivation of food grains to commercial crops. Among food grains, the area under coarse cereals declined by 13.3 per cent between 1970-71 and 2007-08. Similarly, the performance of pulses in terms of area and output was not impressive during the study period. The use of technological inventions in the cultivation of other crops was also not so conspicuous in pulses. Nevertheless, the increase in crop yield has been a major factor for accelerating production in the country since the late 1960s. The use of modern varieties, irrigation and fertilizers were important factors that ensured higher growth in crop production. However, technological and institutional support for a few crops like rice and wheat brought significant changes in crop area and output composition in some regions. The results of crop output growth model indicate that the enhanced capital formation, better irrigation facilities, normal rainfall and improved fertilizer consumption helped to improve crop output in the country.

Mani, Bhalachandran and Pandit (2011) stated that despite its deduced share in India’s GDP, agriculture continues to have a strategic importance in ensuring its overall growth and prosperity. As part of the new economic policy package introduced in the early nineties, there has been a reduction in the rate of public investment. While this may not be bad for the industrial sector, the impact of this policy on agriculture is a matter of concern, in so far as it not only affects steady growth of agriculture but also influences the overall performance of the economy. This is more so because the agricultural sector public investment has also promoted private investment by way of what is termed as the crowding-in phenomenon. This phenomenon together with inter-sectoral linkages is used in their paper to examine the effect of higher public investment for agriculture on the stable growth of this sector as well as of the entire economy. Policy implications of this exercise are important for obvious reasons.

Sharma (2012) argued that during the last two decades Indian agriculture has been facing major challenges like deceleration in growth rate, inter-sectoral and inter-regional equity, declining input efficiency, degradation of natural resources, etc. with consequent adverse effects on food and nutritional security, food inflation and poverty reduction. However, the 11th Plan had some success in reversing the deceleration of agricultural growth witnessed during the 9th and 10th Plan but food inflation still remains a major concern. The growth in agriculture in the 11th Plan is likely to be around 3.2 percent per year, which is higher than 10th Plan growth rate but lower than the target (4.0%) for 11th Plan. The 12th Plan growth target for agriculture sector has been set at 4 percent with foodgrains growth at about 2 percent and non-foodgrains sector (horticulture, livestock and fisheries) growing at about 5-6 percent. However, looking at the growth in agriculture sector in general and high-value agriculture, particularly, horticulture, fisheries, dairy and meat sector during the 11th Plan, there is a need to put additional efforts to achieve 4 percent growth in agriculture.

The failure to achieve targeted growth in agriculture has resulted from the inadequacies of the provision of the critical public goods such as research and development, extension services, surface irrigation, rural infrastructure, etc. on which agricultural growth thrives as well as inappropriate policies. In order to achieve the targeted growth in 12th Plan, we need to address some of these inadequacies. The sector would require substantial increase in investment both by public and private sector in agriculture research and development including extension, rural infrastructure, post-harvest and market infrastructure including storage and processing, reforms in laws related to land markets and marketing of agricultural products, and appropriate price policy. The pricing of agricultural inputs such as irrigation, electricity for pumping water, fertilizer, etc. needs rationalization. The distributional aspects of agricultural credit including inter-regional and inter-class inequalities in access to credit, decline in rural branches, declining share of direct credit, etc. must be addressed. People’s participation, which will help in promoting the bottom up approach of planning process and also help in faster diffusion of the technologies and best practices among farmers, community based actions and participation of disadvantaged sections of the society in developmental process, needs to be strengthened.

Asha latha K. V., Gopinath, and Bhat (2012) stated that the impact of climate change is studied in many aspects in different locations in the country and it is concluded that there is high impact on agriculture compared to any other sector in the country. The study results revealed that the climatic variation such as occurrence of drought have high level of impact on the yield of Rainfed crops. The farmers perception on the impact of climate change on the crops grown in Rainfed condition, such as yield reduction and reduction in net revenue. The farmers already act to the changes in the climatic changes both by adopting the technological coping mechanisms on the positive side and negatively through shifting to other professions. It is concluded that the small and medium Rainfed farmers were highly vulnerable to climate change and to a larger extent the small and medium Rainfed farmers adopted coping mechanisms for climate change compared to large farmers. The study suggests that as the impact of climate change is intensifying day by day it should be addressed through policy perspective at the earliest to avoid short term effect such as yield and income loss and long-term effects such as quitting agricultural profession by the Rainfed farmers.

Ghosal (2012) attempted to examine the temporal and cross state behaviour of the growth, poverty and inequality and also to examine the relations between them and to see whether the temporal behaviour of the incidence of poverty is compatible with the policy evolution followed since independence Further he re-examined whether the conventional hypothesis that growth is a necessary but not sufficient condition for the reduction of poverty across the states hold. Finally, he tried to find out the proximate explanatory factors for the cross state and temporal variations in the incidence of poverty in terms panel regression analysis. He found that Indian economy has indeed achieved a high growth trajectory such that it has been conspicuous during the post reform period with a remarkable structural transformation on an unconventional path which has been accompanied by a tremendous increase in service sector driven growth path. Almost all the states have experienced increase in the growth rates of their real per capita NSDP in varying degrees over the period and the post reform period marks a phase of achievement of very high growth rates for almost all the states. The nature of the growth experienced by the states is found to be divergent .He did not find any uniform relation between temporal behaviour of the growth rates and the Gini inequality across the states Interestingly almost all the states have experienced declining trend in the incidence of poverty in varying degrees during the pre reform period and also over the period from 1993-94 to 2009-10 i.e. during the post reform period. He also found that the relative position of the states regarding their ability to reduce poverty varies remarkably at the inter-temporal level over the period of our study. The time profiles of growth rates, Gini inequalities and the rates of fall in the incidence of poverty do not reveal any definite desired relations. Further he found a paradoxical relation between growth performance and regional concentration of poverty. Moreover our panel regression results confirm that the cross state temporal variations in the social sector expenditure and growth rate of per capita NSDP and the growth rate of per capita NSDP from service sector are the crucial explanatory factors for the cross state temporal variations in the incidence of poverty. So he could plausibly conclude that panel results are highly compatible with the policy evolutions towards poverty reduction and also with nature of the structural transformation with tremendous increase in service sector –led growth Therefore for the further reduction in the magnitude of poverty of the people across the states, more emphasis should be placed not only on the increase in the growth rates but also on the tremendous increase in the social sector expenditures like health ,education etc across the states. However because of the high degree of regional concentration of poverty as compared to that of population in a few states some state specific special strategies for poverty alleviation seem to produce substantial favorable effect on the incidence of poverty.

Raman and Kumari (2012) argued that the growth of agriculture is prerequisite for overall development of Indian economy. It contributes significantly to the export earnings and affects the performance of other sectors of the economy through forward and backward linkages. They analyzed district and regional level disparity in agriculture development in Uttar Pradesh on a number of agricultural parameters. It uses UNDP methodology (subsequently used by a number of others) to standardize various indicators for agricultural attainment in the state of Uttar Pradesh using 13 agricultural development indicators. A composite index has been constructed at the district level and also regional level for two cross-section years 1990-91 and 2008-09. The relative variations and changes in ranks of different districts have been computed during the period under consideration. Evidence shows existence of high and persistent inter-state disparity in agriculture in the state over the years. The transformation of some districts from the level of relatively underperformer to the rank of better performer and vice versa has been witnessed and explained. The findings encourage the authors to conclude that a more determined effort on the part of the policy makers is needed if the development policy has to be made truly inclusive.

Sengupta and Sonwani (2012) argued that India has been witnessing a blinding pace of growth and development in recent times. There is talk of the country leapfrogging into the league of developed nations sooner than later. But this growth has raised concerns from sundry quarters as regards its basic texture and health. Experts are now calling for "sustainable development" and the term has gained currency in the last few years. In spite of fast growth in various sectors, agriculture remains the backbone of the Indian economy. They attempt to tackle and explore the issue of sustainable development in agriculture in India. Further it aims to compare the sustainable agriculture system with the traditional system and the current system in practice, across the dimensions of ecological, economic and social sustainability .It also tries to give long term solutions to solve the problems plaguing the system so that sustainable practices can be promoted and practiced.

Birthal, Joshi, Negi and Agarwal (2013) revisited an earlier study to evaluate how the policy shift influences the patterns and the sources of agricultural growth in India and assesses their implications for regional priorities for higher, more sustainable, and more inclusive agricultural growth. The study found that technology has remained the most important source of agricultural growth due to policy emphasis on cereal-based food security. Nevertheless, agricultural diversification toward high-value crops, driven by a sustained rise in per capita income and urbanization, among other factors, emerged as the next most important source of agricultural growth. The growth in high-value agriculture has come largely from area reallocation from less profitable coarse cereals, mainly millets and sorghum. The contributions of area expansion and commodity prices to agricultural growth have been erratic and small, suggesting that these cannot be sustainable sources of agricultural growth. The sources of agricultural growth, however, have varied widely across the regions; while the irrigated northern region followed a technology-led growth trajectory, the rainfed western and southern regions followed diversification toward high-value crops as the main strategy to enhance and sustain agricultural growth. Agricultural diversification toward high-value crops were found to exhibit a pro-poor bias and thus can serve as an important pathway for smallholders to move out of poverty.In the long run, growth in agriculture must come from technological change and diversification toward high-value crops. To sustain agricultural growth, investment in agricultural research must be increased, and the agricultural research agenda must be revisited in view of the emerging challenges and market opportunities in agriculture and the agrifood industry. Promoting high-value agriculture will require enabling policies, institutions, and infrastructure that facilitate farmers' access to remunerative markets.

Kaur (2013) argued that India's agriculture sector continues to be the lifeline of its people and a key factor in the economy's overall productivity. Historically, India's agriculture growth has lagged growth in the overall economy. In fact, long-term average growth in agriculture has been close to 2%. India's population has been growing at 1.4%. Consequently, India has just managed to maintain its per capita growth in food and non-food crop production. Increasing profitability in agriculture through higher productivity has been an important goal in developing countries like India. It has become more relevant in recent years due to limited scope for expansion of arable land. Increasing yield to their technically highest level may be feasible, through adequate investment in infrastructure and technology i.e. irrigation, land development, storage, markets, etc. Besides appropriate pricing of inputs and outputs, availability of credit and extension services would facilitate access to available technology. Like most other developing countries, India has predominantly been an agrarian economy, with agriculture sector contributing the largest share to gross domestic product (GDP) and employment. Under the colonial regime, Indian agriculture was geared towards the production of commercial crops (tea, coffee, rubber, cotton, etc.), while the food crops suffered from neglect. After independence, India depended heavily on imports of food grains as it inherited a stagnant, low-productivity, food-crop sector. He analyzed the dynamics of structural transformation of the Indian economy and major drivers of transformation, giving an overview of the past achievements and the future challenges in Indian agriculture, finally identifying the key policy issues and strategies to accelerate sustainable broad-based growth in the agriculture sector in the country.

Salam, Anwer and Alam (2013) argued that after the bifurcation of Bihar, the growth rate in terms of both GSDP and NSDP showed remarkable increase in almost all sub-sectors as compared to pre-bifurcation period. However, agriculture and allied sector has accounted miserable growth rate as compared to industrial and services sector. The share of agriculture and allied sector has declined from 46.70 percent to 26.51 percent during 1990-91 to 2008-09. Despite sharp decline of its share in NSDP, agriculture still plays a vital role in the development of Bihar. The urgent need of the hour is to increase Investments in rural infrastructure for water management/soil conservation/ construction of roads to link rural area with urban area etc. With appropriate technology, infrastructure and policy support, it is possible to reverse the declining trend in food grain production and check the migration of the people from Bihar to other states.

Behera (2014) stated that agricultural development is an important component of inclusive growth approach. The broad objective of this paper is to link agriculture development and inclusive growth through farm sector growth driven rural transformation. It has found that agricultural sector growth has increased at a higher rate in Gujarat during 2001-02 to 2010-11 than the India. The growth has been sown higher production of cotton and wheat. It has also influenced some exogenous factors i.e. increased gross cropped and net irrigated area, increase in fertilizer consumption and more use of modern agricultural implements etc. The overall analysis on the growth performance of agriculture and allied activities of Gujarat and India, it seems that Gujarat has facilitated inclusive development in agriculture through the path of livestock and horticulture sector in the view of increasing farm income and farm sector growth.

Lone (2014) argued that agriculture plays an important and vital role in any economy generally, for developing countries particularly and for a country like India especially. Basically India is an agricultural country with 143 million hectares of land as net sown area, the highest percentage of land under cultivation in the world. The country accounts for 17 percent of world's population and ranks at second largest populated country. The country has about 69 percent of population living in its rural areas and villages and the sole source of their livelihood is agriculture and allied activities. Cereal and many ground crop production in agriculture has beset many problems and many scholars have admitted that agricultural diversification towards high value commodities will strengthen agriculture growth in future and will result high remunerative returns to farmers. Again the horticulture and other allied activities have lot of backward and forward linkages which resulted wide employment opportunities and income flow, equally distributed to all in these rural areas hence helps in the development of rural India. The paper will enshrine role of agriculture in rural development and role of diversification to develop agriculture sector itself and is based on secondary data sources, NSSO, Census data is being used in the paper.

Ramachandra, Anand and Manjuprasad (2014) examined the performance of Trends of Agriculture growth and production in India. And also The paper has shown the growth and production has significantly increased from during the last three decades and also highlight the performance of the Indian agriculture growth is also increased over the period of time the present paper mainly focused on the secondary sources with help of the statistical tools such as mean, standard deviation, covariance, CGR, regression methods has been used for study purpose.

Kaur (2015) attempted to analyze the growth of agricultural credit in India for a period of 2000-01 to 2011-12. For the study purpose, relevant data has been collected from secondary sources. Percentages and compound annual growth rates are used for data analysis. The study reveals that flow of institutional credit to agriculture has increased over a period of time. The amount of loans issued to agriculture both as direct and indirect finance has shown an increase during the reference period. At the same time, the loans outstanding have also grown over a period of time.

2.3 Studies Relating to Measurement of Volatility

There are a lot of studies related to the measurement of volatility. In this chapter we have presented those studies which related to the measurement of volatility by linear ARCH or GARCH method and multivariate GARCH model.

2.3.1 Econometric Theoretical Studies Relating to Measurement of Volatility: Linear ARCH and GARCH Model and Extension of GARCH Model

For measurement of volatility in this thesis we have considered linear Autoregressive Conditional Heteroskedasticity (ARCH (q)) and generalized autoregressive conditional heteroskedastic model (GARCH (p, q)) model. In his seminal paper **Engle (1982)** introduced the Autoregressive Conditional Heteroskedasticity (ARCH) model or ARCH (q) Model. He argued that traditional time series tools such as autoregressive moving average (ARMA) models (**Box and Jenkins, 1970**) for the mean have been unmitigated to essentially comparable models for the variance. **Engle (1982)** suggested that one possible parameterization for variance is to express variance as a linear function of past squared values of the process. This model is known as the linear ARCH (q) model. Engel also discussed the Maximum likelihood (ML) based inference procedures for the ARCH class of models under this distributional assumption.A nonparametric test for ARCH (q) has been suggested by **Gregory (1989)** which can be derived from a finite state Markov chain approximation. **Robinson (1991)** presents an LM test for very general serially dependent heteroskedasticity. The small sample performance of some of these estimators and test statistics have been also analyzed by **Engle, Hendry, and Trumble (1985), Diebold and Pauly (1989), Bollerslev and Wooldridge (1992), and Gregory (1989)**. ARCH-type models can also be estimated directly with Generalized Method of Moments (GMM) as an alternative of ML estimation. This point was suggested and implemented by **Mark (1988) Bodurtha and Nelson (1991) Glosten, Jagannathan, and Runkle (1991), Simon (1989) and Rich, Raymond, and Butler (1990)** and in a closely related context by **Harvey (1989)** and **Ferson (1989).** Bayesian inference procedures within the ARCH class of models are developed in a series of papers by **Geweke (1988, 1989a, b),** who uses Monte Carlo methods to determine the exact posterior distributions. **Tsay (1987) Bera and Lee (1989,1991), Kim and Nelson (1989) Wolff (1989) Cheung and Pauly (1990) and Bera, Higgins, and Lee (1991)** also studied the relationship between the time-varying parameter class of models and the linear ARCH(q) model. Similarly, in **Weiss (1986) and Higgins and Bera (1989)** comparisons to the bilinear time series class of models are considered.

Bollerslev (1986) provided an alternative and more flexible lag structure by the Generalized ARCH, or GARCH (p, ***q),*** mode. In his paper he suggested a natural generalization of the ARCH (Autoregressive Conditional Heteroskedastic) process introduced in **Engle (1982)**. This model allows for past conditional variances in the current conditional variance equation. Stationarity conditions and autocorrelation structure for this new class of parametric models are derived and Maximum likelihood estimation and testing are also considered. **Nelson (1990)** argued that much of modern finance theory is cast in terms of continuous time stochastic differential equations, while virtually all financial time series are available at discrete time intervals only. This apparent gap between the empirically motivated ARCH models and the underlying economic theory is the main focus of **Nelson (1990).** He shows that the discrete time GARCH (1, 1) model converges to a continuous time diffusion model as the sampling interval gets arbitrarily small. Similarly, **Nelson (1992)** shows that if the true model is a diffusion model with no jumps, then the discrete time variances are consistently estimated by a weighted average of past residuals as in the GARCH(1, 1) formulation. **Drost and Nijman (1991)** argued that the class of GARCH (p, ***q)*** models is closed under temporal aggregation, appropriately defined in terms of best linear projections. Also, **Diebold (1986b, 1988)** shows convergence towards normality of a martingale process with ARCH errors under temporal aggregation using a standard central limit theorem type argument.

Among the many extensions of the standard GARCH models nonlinear GARCH (NGARCH) was proposed by **Engle and Ng** in **1993**. The integrated GARCH (IGARCH) is a restricted version of the GARCH model, where the sum of all the parameters sum up to one. **Nelson (1991)** introduced the exponential GARCH (EGARCH) model where the logarithm of the variance is important rather than the level. In the GARCH-in-mean (GARCH-M) model a heteroskedasticity term is added into the mean equation. The quadratic GARCH (QGARCH) model and the **Glosten- Jagannathan- Runkle** GARCH (GJR-GARCH) model **(1993)** can handle asymmetric effects of positive and negative shocks in the GARCH process. The threshold GARCH (TGARCH) model is similar to GJR-GARCH with the specification on conditional standard deviation instead of conditional variance. **Hentschel (1995)** introduced the concept of Family GARCH (FGARCH) which is an omnibus model that is a mix of other symmetric or asymmetric GARCH models.

2.3.2 Empirical Literature Related to Volatility of Agricultural Sector

The present literature suggests that specific study relating to volatility of Indian agricultural sector are lacking. There are huge numbers of studies associated with the problem of volatility in the agricultural sector for international context. Among them Shively (1996), Fousekis and Pantzios (2000), Manfredo, Leuthold, and Irwin (2001), Apergis and Rezitis (2003) , Buguk, Hudson, and Hanson (2003), Yang, Zhang and Leatham (2003), Jordaan, Grové, Jooste and Alemu (2007), Valenzuela, Hertel, Keeney Reimer (2007), Easwaran and Ramasundaram (2008), Meyers and Meyer (2008), Du, Yu, and Hayes (2009), Serra and Zilberman (2009), Ajetomobi (2010), Gilbert and Morgan (2010), McConnell, Dohlman and Haley (2010), Huchet-Bourdon (2011), Serra (2011), Pop and Ban (2011), Wright (2011), Trujillo-Barrera, Mallory, and Garcia (2012), Gouel (2013), Kornher and Kalkuhl (2013), Minot (2014) are repotted here.

Shively (1996) investigated the changes in maize price levels and variability in Ghana. A model of wholesale price determination is reviewed in which grain stocks are held for speculative storage as well as export to neighboring countries in the Sahel. To test the model, an

Autoregressive Conditionally Heteroskedastic (ARCH) regression is applied to monthly maize data for two markets over the period 1978-93. The regression is used to measure changes in maize price volatility in Ghana, and to infer the importance of past prices, domestic and regional production, and commodity storage and trade in explaining these changes.

Fousekis and Pantzios (2000) estimated a dual model of price risk in Greek agriculture and to assess the effects of this type of risk on farmers' production decisions. After this they analyzed the rate of Total Factor Productivity (TFP) in the sector, during 1968-96, into components of interest. The empirical results suggest that the Greek farmers are risk averse. When the variance of output price increases by 100% the Greek farmers require an increase in the expected output price by 9.1% in order to maintain the same supply level. The technical change effects are the most important determinant of TFP growth, followed by the scale effects, the price risk effects, and the effects arising from the adjustment in the fixed factor

Manfredo, Leuthold, and Irwin (2001) argued that economists and others need estimates of future cash price volatility to use in risk management evaluation and education programs. They evaluated the performance of alternative volatility forecasts for fed cattle, feeder cattle, and corn cash price returns. Forecasts include time series (e.g. GARCH) implied volatility from options on futures contract, and composite specifications. The overall finding from this research consistent with the existing volatility forecasting literature, is that no single method of volatility forecasting provides superior accuracy across alternative data sets and horizons. However, evidence is provided suggesting that risk managers and extension educators use composite methods when both time series ant1 implied volatilities are available.

Apergis and Rezitis (2003) investigated volatility spillover effects across agricultural input prices, agricultural output prices and retail food prices using the technique of Generalised Autoregressive Conditional Heteroscedastic (GARCH) models. The empirical findings show that the volatility of both agricultural input and retail food prices exerts significant, positive spillover effects on the volatility of agricultural output prices. Moreover, the volatility of agricultural output prices has a significant, positive impact on its own volatility. Agricultural output prices are shown to be more volatile than agricultural input and retail food prices.

Buguk, Hudson, and Hanson (2003) analyzed the price volatility spillovers in the U.S. catfish supply chain based on monthly price data from 1980 through 2000 for catfish feed, its ingredients, and farm- and wholesale-level catfish. The exponential generalized autoregressive conditional heteroskedasticity (EGARCH) model was used to test univariate volatility spillovers for prices in the supply chain. Strong price volatility spillover from feeding material (corn, soybeans, and menhaden) to catfish feed and farm- and wholesale-level catfish prices was detected.

Yang, Zhang and Leatham (2003) examined futures price and volatility transmissions among three major wheat production and exporting regions, the United States (US), Canada and the European Union (EU) over the recent six-year study period of 1996 - 2002. The price transmission pattern shows that Canadian prices are much more influenced by the US prices than the US prices are influenced by Canadian prices. The EU is highly self-dependent and may exert some influence on the US prices in the long run but not vice versa. The volatility transmission pattern, however, shows that volatility is transmitted from Canada and the EU to the US but not vice versa. The volatility is also transmitted from the EU to Canada but not vice versa. Overall, there is no distinctive leadership role in international wheat markets, with all three markets exhibiting features

Jordaan, Grové, Jooste and Alemu (2007) determined the conditional volatility in the daily spot prices of the crops traded on the South African Futures Exchange (yellow maize, white maize, wheat, sunflower seed and soybeans. The volatility in the prices of white maize, yellow maize and sunflower seed have been found to vary over time, suggesting the use of the GARCH approach in these cases. Using the GARCH approach, the conditional standard deviation is the measure of volatility, and distinguishes between the predictable and unpredictable elements in the price process. This leaves only the stochastic component and is hence a more accurate measure of the actual risk associated with the price of the crop. The volatility in the prices of wheat and soybeans was found to be constant over time; hence the standard error of the ARIMA process was used as the measure of volatility in the prices of these two crops. When comparing the medians of the conditional standard deviations in the prices of white maize, yellow maize and sunflower seed to the constant volatilities of wheat and soybeans, the price of white maize was found to be the most volatile, followed by yellow maize, sunflower seed, soybeans, and wheat respectively. These results suggest that the more risk-averse farmers will more likely produce wheat, sunflower seed and to a lesser extent soybeans, while maize producers are expected to utilise forward pricing methods, especially put options, at a high level to manage the higher volatility.

Valenzuela, Hertel, Keeney Reimer (2007) used Computable General Equilibrium (CGE) models for global agricultural market analysis. Concerns are sometimes raised, however, about the quality of their output since key parameters may not be econometrically estimated and little emphasis is generally given to model assessment. They addressees the latter issue by developing an approach to validating CGE models based on the ability to reproduce observed price volatility in agricultural markets. They show how patterns in the deviations between model predictions and validation criteria can be used to identify the weak points of a model and guide development of improved specifications with firmer empirical foundations.

Easwaran and Ramasundaram (2008) argued that in any agriculture-dominated economy, like India, farmers face not only yield risk but price risk as well. Commodity futures and derivatives have a crucial role to play in the price risk management process, especially in agriculture. They investigated into the futures markets in agricultural commodities in India. The statistical analysis of data on price discovery in a sample of four agricultural commodities traded in futures exchanges have indicated that price discovery does not occur in agricultural commodity futures market. The econometric analysis of the relationship between price return, volume, market depth and volatility has shown that the market volume and depth are not significantly influenced by the return and volatility of futures as well as spot markets. The Bartlett’s test statistic has been found insignificant in both the exchanges, signifying that the futures and spot markets are not integrated. The exchange-specific problems like thin volume and low market depth, infrequent trading, lack of effective participation of trading members, non-awareness of futures market among farmers, no well-developed spot market in the vicinity of futures market, poor physical delivery, absence of a well-developed grading and standardization system and market imperfections have been found as the major deficiencies retarding the growth of futures market. The future of futures market in respect of agricultural commodities in India, calls for a more focused and pragmatic approach from the government. The Forward Markets Commission and SEBI have a greater role in addressing all the institutional and policy level constraints so as to make the agricultural commodity futures and derivatives a meaningful, purposeful and vibrant segment for price risk management in the Indian agriculture.

Meyers and Meyer (2008) analyzed the food price surge of 2005 to 2008 in order to better understand the factors causing higher and more volatile food prices during this period, to ascertain the relative importance and possible persistence of the different factors, and to suggest possible implications for future market behavior and policy reactions. Given the highly uncertain outlook for petroleum price and its increasing impact on agricultural and food prices, the near-term outlook for major grains and oilseeds is generated from the latest USDA crop estimates and the FAPRI stochastic analysis of early 2008. Price projections to 2010/11 crop year are generated for major grains and oilseeds, given petroleum prices that average $48, $67, and $95 per barrel.

Du, Yu, and Hayes (2009) examined the roles of various factors influencing the volatility of crude oil prices and the possible linkage between this volatility and agricultural commodity markets. Stochastic volatility models are applied to weekly crude oil, corn, and wheat futures prices from November 1998 to January 2009. Model parameters are estimated using Bayesian Markov chain Monte Carlo methods. The main results are as follows. Speculation, scalping, and petroleum inventories are found to be important in explaining oil price variation. Several properties of crude oil price dynamics are established, including mean-reversion, a negative correlation between price and volatility, volatility clustering, and infrequent compound jumps. We find evidence of volatility spillover among crude oil, corn, and wheat markets after the fall of 2006. This could be largely explained by tightened interdependence between these markets induced by ethanol production.

Serra and Zilberman (2009) looked at how price volatility in the Brazilian ethanol industry changes over time and across markets by using a new methodological approach suggested by Seo (2007). The main advantage of Seo's proposal over previously existing methods is that it allows to jointly estimating the co-integration relationship between the price series investigated and the multivariate GARCH process. Our results suggest that crude oil prices not only influence ethanol price levels, but also their volatility. Increased volatility in crude oil markets results in increased volatility in ethanol markets. Ethanol prices, on the other hand, influence sugar price levels and an increase in their volatility levels also impacts, though less strongly, on sugar markets.

Ajetomobi (2010) stated that Nigeria is among many African countries that have engaged in agricultural liberalization since 1986 in the hope that reforms emphasizing price incentives will encourage producers to respond. Till now, the reforms seem to have introduced greater uncertainty into the market given increasing rates of price volatility. He gave a model of supply responses in Nigerian agriculture that include the standard arguments as well as price risk. The data come from the AGROSTAT system of the statistical division of the Food and Agriculture Organization (FAO), Federal Ministry of Agriculture statistical bulletins, Central Bank of Nigeria statistical bulletins, Federal Office of Statistics Agricultural Survey Manual and the World Bank Africa Development Indicators. The data are analysed using autoregressive distributed lag and error correction models. The results indicate that producers are more responsive not only to price but to price risk and exchange rate in the structural adjustment programme (SAP) period than in the commodity marketing board (CMB) period. Following deregulation, price risk needs to be meaningfully reduced for pulse and export crops, especially cowpea and cocoa.

Gilbert and Morgan (2010) argued that the high food prices experienced over recent years have led to the widespread view that food price volatility has increased. However, volatility has generally been lower over the two most recent decades than previously. Variability over the most recent period has been high but, with the important exception of rice, not out of line with historical experience. There is weak evidence that grains price volatility more generally may be increasing but it is too early to say.

McConnell, Dohlman and Haley (2010) stated that rising pressure on sugar prices was intensified by supply disruptions in 2009, driving prices to double the long-term average. Higher production costs and growing ethanol use in Brazil set the stage for higher prices, but policy-induced production swings among Asian countries are the main source of price volatility in world markets. Although dramatic fluctuations in world prices have affected U.S. sugar prices, domestic sugar policy continues to drive U.S. sugar price movements.

Huchet-Bourdon (2011) affirmed that recent years have witnessed a sharp increase in many commodity prices. This report examines the question of whether commodity price volatility has materially changed with the rapid run up in world prices in 2006-09, followed by an equally sharp decline in many commodity prices. The report analyses international price volatility for selected agricultural commodities over the past half-century and their relationship with crude oil, fertiliser and the euro-dollar exchange rates. The analysis utilises different data sources, frequency of price observations, periods of observation, price volatility measures and a number of statistical tests to examine the various dimensions of the issue.

Serra (2011) argued that previous literature on volatility links between food and energy prices is scarce and mainly based on parametric approaches. They assess this issue by using a semi-parametric GARCH model recently proposed by Long et al. (2009), which is essentially a nonparametric correction of the parametric conditional covariance function. They focus on price links between crude oil, ethanol and sugar prices in Brazil. Results suggest strong volatility links between the prices studied. They also suggest that parametric approximations of the conditional covariance matrix may lead to misleading results and can be improved using nonparametric techniques.

Pop and Ban (2011) aimed to present the main instruments used in the economic literature for measuring the price risk, pointing out on the advantages brought by the conditional variance in this respect. The theoretical approach will be exemplified by elaborating an EGARCH model for the price returns of wheat, both on Romanian and on international market. To our knowledge, no previous empirical research, either on price risk measurement for the Romanian markets or studies that use the ARIMA-EGARCH methodology, have been conducted. After estimating the corresponding models, they compared the estimated conditional variance on the two markets.

Wright (2011) stated that recent volatility of prices of major grains has generated a wide range of analyses and policy prescriptions that reveal the inability of economists to approach a consensus on the nature of the phenomenon and its implications for policy. This review of market events and their economic interpretations finds that recent price spikes are not as unusual as many discussions imply. Further, the balance between consumption, available supply, and stocks seems to be as relevant for our understanding of these markets as it was decades ago. Though there is much to be learned about commodity markets, the tools at hand are capable of explaining the main forces at work, and of giving good guidance to policymakers confronted with a bewildering variety of expensive policy prescriptions.

Trujillo-Barrera, Mallory, and Garcia (2012) analyzed recent volatility spillovers in the United States from crude oil using futures prices. Crude oil spillovers to both corn and ethanol markets are somewhat similar in timing and magnitude, but moderately stronger to the ethanol market. The shares of corn and ethanol price variability directly attributed to volatility in the crude oil market are generally between 10%- 20%, but reached nearly 45% during the financial crisis, when world demand for oil changed dramatically. Volatility transmission is also found from the corn to the ethanol market, but not the opposite. The findings provide insights into the extent of volatility linkages among energy and agricultural markets in a period characterized by strong price variability and significant production of corn-based ethanol.

Gouel (2013) argued that when food prices spike in countries with large numbers of poor people, hunger and malnutrition are very likely to result in the absence of public intervention. For governments, this is also a case of political survival. Government actions often take the form of direct interventions in the market to stabilize food prices, which goes against most international advice to rely on safety nets and world trade. Despite the limitations of food price stabilization policies, they are widespread in developing countries. He attempts to untangle the elements of this policy conundrum. Price stabilization policies arise as a result of international and domestic coordination problems. At the individual country level, it is in the national interest of many countries to adjust trade policies to take advantage of the world market in order to achieve domestic price stability. When countercyclical trade policies become widespread, the result is a thinner and less reliable world market, which further decreases the appeal of laissez-faire. A similar vicious circle operates in the domestic market: without effective policies to protect the poor, such as safety nets, food market liberalization lacks credibility and makes private actors reluctant to intervene, which in turn forces government to step in. The current policy challenge lies in designing policies that will build trust in world markets and increase trust between public and private agents.

Kornher and **Kalkuhl (2013)** illuminated about the ongoing discussion on the drivers of food price volatility. Based on theoretical considerations, economical, agricultural, and political determinants of domestic price volatility are identified and discussed. They used a dynamic panel for estimation purpose to account for country fixed effects and persistence of volatility. Two approaches are followed in order to consistently estimate the impact of time-invariant variables. First, system GMM using levels instead of first differences and, second, a two-step IV estimation using the residuals from the system GMM estimation. They suggested that stocks, production, international price volatility, and governance significantly affect domestic price variability. Furthermore, improved functionality of markets and reduced transaction costs can stabilise prices. With respect to agricultural policies, public stockholding seems to be associated with less volatility, whereas trade restrictions do not enhance price stabilisation. Lastly, landlocked countries experience less variability in grain prices, while African countries have more volatile prices than countries on other continents.

Minot (2014) argued that the food price crisis of 2007–2008 and recent resurgence of food prices have focused increasing attention on the causes and consequences of food price volatility in international food markets and the developing world, particularly in sub-Saharan Africa. He examined the patterns and trends in food price volatility using an unusually rich database of African staple food prices. He found that international grain prices have become more volatile in recent years (2007–2010) but no evidence that food price volatility has increased in the region. This contrasts with the widespread view that food prices have become more volatile in the region since the global food crisis of 2007–2008. In addition, the results suggest that price volatility is lower for processed and tradable food than for non-tradable food that volatility is lower in the major cities than in secondary cities, and that maize price volatility is actually higher in countries with the most active intervention to stabilize maize prices. These findings suggest that greater attention should be given to the (high) level of food prices in the region rather than volatility per se; that regional and international trade can play a useful role in reducing food price volatility, and that traditional food price stabilization effort may be counterproductive.

2.4 Studies Related to Total Factor Productivity Growth (TFPG)

In the literature there exist a lot of studies which related to the estimation of the TFPG of the agricultural sector as well as the other areas. In this section we presented those studies which give some theoretical foundation of the estimation of the TFPG and some empirical studies related to the estimation of TFPG in the agricultural sector both in the international context as well as the Indian context.

2.4.1 Studies on Measurement of Total Factor Productivity Growth (TFPG)

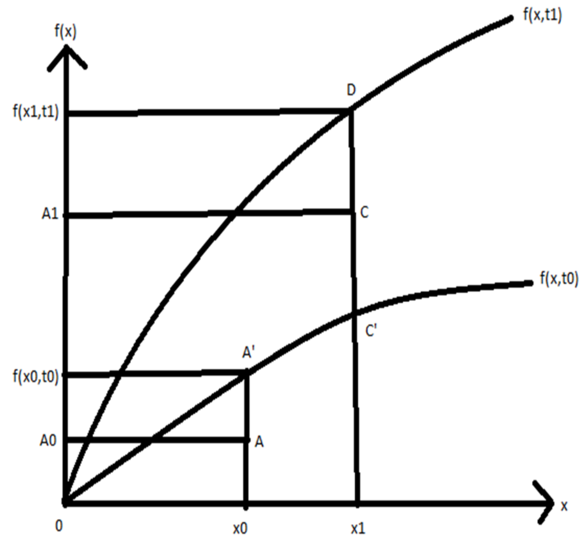
TFPG measures the amount of increase in total output which is not accounted for the increase in total inputs and thus measures shift in output due to the shift in the production function over time, holding all inputs constant (**Abramovitz, 1956; Denison, 1962, 1967, 1985; Hayami et al, 1979**). Input specific productivities like labor productivity and capital productivity are partial measures of industrial productivity. To have a complete measure, one must have to consider a measure that relates output to all the factor inputs used in the production process. Such a measure is known as Total Factor Productivity (**Tinbergen, 1942**). Since the present thesis is concerned with TFPG, to keep the discussion within limit, studies on TFPG will be discussed only.

A large amount of literature exists around the globe dealing with the estimation of TFPG of Agriculture sector for India as well as countries other than India considering different time periods and using different methodologies.

2.4.1.1 Theoretical Literature on Total Factor Productivity Growth

TFPG can be measured by (i) Growth Accounting Approach-GAA [i.e. by constructing either Solow Index (**Solow, 1957**), or Kendrick Index (**Kendrick, 1956, 1961, 1973**) or Translog-Divisia Index (**Solow, 1957**; **Jorgenson and Griliches, 1967**; **Christensen and Jorgenson, 1969, 1970**); (ii) Econometric (Parametric) Approach (i.e. by estimating production function or cost function); (iii) Non-parametric Approach (i.e. through Data Envelopment Analysis (DEA)).

Total factor productivity growth measures growth in output which is not accounted by growth in inputs. In order to get an idea regarding the extent of Total factor productivity growth the following diagram is considered:



where t= time period; $t_1 > t_0$ and x = single input and f(x) = single output, $y_0 = f(x, t_0)$ and $y_0 = f(x, t_1)$ are the production functions at time period 0 and 1 respectively.

Production Function: y = f(x), shows the maximum output y obtainable from a given input x. If $(y^/, x^/)$ be the observed plan of the firm then the plan is technically efficient if $y^/ = f(x^/)$ and technically inefficient if $y^/ < f(x^/)$.

Measure of technical efficiency E: $E = \{y^/ / f(x^/)\}$; $0<E<1$

In the above diagram, $AA^/$ = inefficiency because with x_0 amount of input, maximum $f(x_0, t_0)$ amount of output can be produced by using the frontier but the entire input is not efficiently used that is why in reality only A_0 amount of output has been produced which is lesser than $f(x_0, t_0)$.

$$\text{Inefficiency} = \frac{\text{Actual output}}{\text{Maximum producible output}} = \frac{\text{A0}}{\text{f(x0)}}$$

Similarly, with x_1 amount of input, maximum $f(x_1, t_1)$ amount of output can be produced by using the frontier but the entire input is not efficiently used that is why in reality only A_1 amount of output has been produced which is lesser than $f(x_1, t_1)$.

$$\text{Inefficiency} = \frac{\text{Actual output}}{\text{Maximum producible output}} = \frac{A1}{f(x1)}$$

Movement from A to C = Movement from A to A/ (Efficiency Change)

+ Movement from A/ to C/ (Scale Efficiency Change)

+ Movement from C/ to D

- Movement from D to C (Efficiency Change)

Where CC/ = Technical Change = {Movement from C/ to D – Movement from D to C}

The best practice level or a frontier is the production function giving the maximum possible output given a set of inputs. However in order to reach the best practice level, knowledge of this level or the frontier is needed and also the distance from the frontier. In this context it is also important to distinguish between technological progress and changes in technical efficiency. Technological progress occurs through the changes in the best practice production frontier. Total factor productivity change is the sum of rate of technological progress and changes in technical efficiency. Thus it is important to recognize that changes in technical efficiency affect total factor productivity. In the literature reference is made to allocative and technical efficiency. Allocative efficiency occurs when a firm employs its factors in the correct proportions. On the other hand, technical efficiency arises when a firm makes the best use of its inputs. Technical efficiency is obtained by minimizing the cost incurred at each level of activity (**Ray, 2006**).

2.4.1.2 Measurement of TFPG using Growth Accounting Approach

Total factor productivity (TFP) may be defined as the ratio of output to a weighted combination of inputs. Various TFP indexes suggested differ from one another with regard to the weighting scheme involved. In most empirical studies either the Kendrick index or the Solow index has been used.

A. Solow Index

B. Kendrick index

C. Divisia Index – Translog Index

A. Measurement of TFPG using Solow Index

This index is based on the Cobb-Douglas production function. Under the assumption of constant returns to scale, autonomous Hicks-neutral technological progress and payment to factors according to marginal product, the following equation is obtained

$$\frac{\dot{A}}{A} = \frac{\dot{Y}}{Y} - [(1-\beta)\frac{\dot{L}}{L} + \beta\frac{\dot{K}}{K}]$$

Where Y denotes output, L denotes labour, K denotes capital and β denotes the income share of capital. Dot stands for the time derivative.

The discrete form of the above equation

$$\frac{\Delta A}{A} = \frac{\Delta Y}{Y} - [(1-\beta)\frac{\Delta L}{L} + \beta\frac{\Delta K}{K}]$$

$\frac{\Delta A}{A}$ is basically the extent of TFPG.

B. Measurement of TFPG using Kendrick Index

Let us assume that there is one homogeneous output denoted by Y and there are two factors of production: capital denoted by K and labour denoted by L. Further, let w_0 and r_0 denote the factor rewards of labour and capital in the base year. Then the Kendrick index for year t may be written as

$$A_t = \{Y_t / (w_0L_t + r_0K_t)\}$$

Under the assumptions of constant returns to scale, perfect competition and payment to factors according to their marginal product, the total earnings of labour and capital in the base year is exactly equal output of that year; so that A_0 is equal to unity by definition. The Kendrick index may be interpreted as the ratio of actual output to the output which will be resulted from increased input in the absence of technological change.

for any $t \neq t_0$, A_t will differ from unity. The extent of TFPG is measured by the departure of A_t from unity.

C. Measurement of TFPG using Divisia Index – Translog Index

Consider an aggregate production function with two factors of production $Y = F(K, L, T)$

where Y denotes aggregate output, K denotes aggregate capital, L denotes aggregate labour and T denotes time.

The share of the factors will be $V_K = (rK / pY)$ & $V_L = (wL / pY)$

$\Delta \log Y = V_K (\Delta \log K) + V_L (\Delta \log L) + V_T$

Where $\Delta \log Y = \log Y(T) - \log Y(T\text{-}1)$

$\Delta \log K = \log K(T) - \log K(T\text{-}1)$

$\Delta \log L = \log L(T) - \log L(T\text{-}1)$

and $V_K = (1/2) [V_K(T) + V_K(T\text{-}1)]$ & $V_L = (1/2) [V_L(T) + V_L(T\text{-}1)]$

This expression for V_T is termed the average translog quantity index of technological change.

2.4.1.2 Measurement of TFPG using Parametric Approach

A. Estimation of TFPG using Production Function

B. Estimation of TFPG using Cost Function

A. Estimation of TFPG using Production Function

Since TFPG measures the shift of the production function over time, in order to estimate TFPG using production function, we basically start with the assumption of any particular form of the production function and add time as an argument in that function.

The responsiveness of the production function (Y) with respect to time $\frac{\partial y}{\partial t}$ gives us the extent of TFPG. The researchers can assume different types of production function like Cobb-Douglas, CES, Translog etc.

B. Estimation of TFPG using Cost Function

Cost Function is given by: $C = C (P_K, P_L, T)$

where P_K = Per unit price of capital, P_L = Per unit price of labour and T = time

To measure technical progress, we have to introduce above equation. If the coefficient of T is negative and statistically significance, then we have technical progress.

Total factor productivity growth = $\frac{\partial \log C}{\partial T}$

Negative of the coefficient $\frac{\partial \log C}{\partial T}$ gives us the extent of TFPG. To get positive TFPG, cost function should fall over time.

2.4.1.4 Measurement of TFPG Using Non parametric approach of Data Envelopment Analysis (DEA)

The non-parametric approach of TFP growth measure differs from the other approaches in the sense that it does not require any explicit specification of production technology nor does it require any econometric estimation. Only a few assumptions about the production technology are needed. No assumption regarding market structure adds more flexibility to the analysis. This approach employs mathematical programming to measure TFP growth on the basis of actual input-output observations. A benchmark (or reference) technology is constructed on the basis of sample observations and this benchmark technology is then used to decompose the changes in productivity into its components like technical change, technical efficiency change and scale efficiency change. The most widely used measure of TFP growth is followed by constructing Malmquist Productivity Index (MPI). MPI scales output levels up or down radially with respect to the benchmark technology. Commonly the measurement of TFP growth using MPI is done through Data Envelopment Analysis (DEA). DEA is a ‘data-oriented’ approach for evaluating the performance of multiple decision making units (DMUs).

In DEA, without explicitly specifying a production function, the maximum producible output is constructed using the sample observations and on the basis of a few assumptions like feasibility, convexity of the production possibility set, free disposability of inputs and outputs and also of CRS or VRS. In DEA, the efficiency frontier envelops all the data.

In the formulation of DEA by **Charnes, Cooper and Rhodes (CCR) (1978, 1981)**, the data on market prices are not available. Shadow prices are chosen with the help of a linear programming problem so as to maximize the average productivity. Distance functions can be derived by suitably defining a non-negative scale factor. Productivity indices can be obtained from the distance functions. However, later extension of DEA allow for reformulation of the original problem to take into account the market price.

CCR (1978, 1981) induced the method of DEA to address the problem of efficiency measurement for DMUs with multiple inputs and multiple outputs in the absence of market prices. However, the CCR-DEA model measures technical efficiency of a firm under the assumption of CRS.

Later, **Banker, Charnes and Cooper (BCC) (1984)** made extensions of the CCR model by incorporating technologies exhibiting VRS.

Caves, Christensen and Diewert (1982) showed that for translog production function, T ö rnqvist output and indexes are equal to mean of two MPIs. They introduce MPI as ratio of output distance functions without any aggregation of inputs.

F ä re, Grosskopf, Lindgren and Roos (1992) used mathematical programming to evaluate the distance functions that can be used in empirically measuring MPIs. Further, they also decompose the measured MPI into technical change or ‘shift in’ production frontier and ‘catching up’ showing movements towards (or away from) the frontier, assuming CRS and any scale effect, by definition, is ruled out.

However, in a subsequent paper, **Färe, Grosskopf, Norris and Zhang (FGNZ) (1994)** followed an extended decomposition proposed by **Färe, Grosskopf, and Lovell (1994)** to further single out the returns to scale effect. FGNZ calculate a world benchmark frontier and compare each country with respect to this benchmark by allowing VRS. The model is applied to analyze productivity growth in 17 OECD countries over 1979-88. The use of CRS and VRS by FGNZ within the same decomposition of MPI is later criticized by **Ray and Desli (1997)**.

Schimmelpfennig and Thirtle (1994) applied Granger Causality tests and Cointegration tests to investigate whether any causal relationship between TFP and a few explanatory variables exists. To estimate the model, they use the data on agriculture for UK, 10 EC countries and the USA. A long-run relationship is found between TFP and research spending.

Ray and Desli (1997) argued that the use CRS and VRS by **FGNZ (1994)** within same decomposition of MPI as not being consistent. They provide a modified decomposition by using the VRS frontier as a benchmark. In that decomposition, scale efficiency change is obtained by considering both the constant returns to scale technology and the variable returns to scale technology. However, when one estimating cross-period efficiency scores (which is measured by comparing actual output of a firm in period *t* with the maximum producible output from period *t* +1 input set.) under a VRS technology may result in linear programming infeasibilities for some observations.

Färe, Grifell-Tatjé, Grosskopf and Lovell (1997) provide a further decomposition of technical change index into an index of magnitude of technical change, an output-bias index and an input-bias index.

In **2011, Pastor, Asmild, and Lovell** provided a new Malmquist Index which is known as the Biennial Malmquist Index (BMI) which uses the same decomposition as provide by Ray and Desli but it solves the infeasibility problem associated with the Ray-Desli decomposition of the Malmquist Index. Instead of using a contemporaneous production possibility frontier, they estimate the technical efficiency of a production unit with reference to a biennial production possibility frontier.

2.4.2 Empirical Literature Related to Estimation of TFPG in the Agricultural Sector in International Context

In empirical literature, lots of studies deal with the measure and estimation of Total Factor Productivity Growth in the Agricultural Sector in International context. Some of the literatures basically focused in the recent studies are presented below. These studies are Ball (1985); Frisvold G. and K. Ingram (1995); Fulginiti and Perrin (1998); Diewert W. E. and Nakamura A. O. (2002); Ehui and Jabbar (2002); Coelli, Rahman.and Thirtle (2003); Thirtle, Lin and Piesse (2003), Kwon and Lee (2004); Rae et al (2006); Tonini and Jongeneel (2006); Ma et al (2007); Binam, Gockowski and Nkamleu (2008); Kumar, Mittal and Hossain (2008); Asadullah and Rahman (2009); Hoang Viet-Ngu and T. Coelli (2009); Loureiro (2009); O’Donnell C.J. (2009); Vries (2009); Avila and Evenson (2010); Fuglie (2010); Jin et al (2010); Headey, Alauddin, Rao (2010); Hassanpour et al (2010); Rezitis (2010); Shahabinejad and Akbari (2010); Lee and Cheng (2011); Rezek, Campbell and Rogers (2011); Yeboah *et al* (2011); Mohan and Matsuda (2013); Hassan et al (2014) and many more.

Ball (1985) constructed Tornqvist-Theil indexes of outputs and inputs in U.S. Agriculture for the period 1948-79. These data are used to construct indexes of productivity growth over the postwar period. The productivity indexes can be derived from a flexible multi-output-multi-factor representation of the structure of production constrained to constant returns to scale. Total factor productivity grew at an average annual rate of 1.75%, compared with 1.70% per year estimated by the U.S. Department of Agriculture. The similar estimates of productivity growth overshadow some important differences in measurement of individual inputs.

Kawagoe et al. (1985) estimated cross-country production functions for 1970 and 1980 by using data for 1960, 1970 and 1980 in 21 developed countries and 22 less developed countries. They found that technological regression during both decades for the less developed countries, but technological progress in the developed countries. **Kawagoe and Hayami (1985)** use an indirect production function and find similar results in that data set.

Lau and Yotopoulos (1989) estimated an alternative meta-production function for agriculture with the cross-section data for 43 countries and three years (1960, 1970 and 1980) constructed and used by Kawagoe, Hayami and Ruttan and Hayami and Ruttan in their studies. By allowing for country-specific efficiency factors and using a flexible functional form - the transcendental logarithmic production function - strikingly different result from those of Kawagoe, Hayami and Ruttan are obtained. In particular, they found that elasticity of output with respect to machinery is variable and the degree of local returns to scale is not constant and increases with the usage of machinery.

Fulginiti and Perrin (1993) estimate technical progress by using Cobb-Douglas production specification for LDCs for the period 1961-1985. They found that technological regression for 14 of the 18 countries. It is possible, as suggested by the authors that interferences with the agricultural sector such as price policies had a depressing effect on incentives so as to stifle potential productivity gains.

Frisvold G. and K. Ingram (1995) examined sources of agricultural growth in sub-Saharan Africa. Growth in the stock of traditional inputs (land, labor, and livestock) remains the dominant source of output growth. Growth in modern input use was of secondary importance, but still accounted for a 0.2-0.4% annual growth rate in three of four sub-regions. Econometric results support earlier studies that suggest that land abundance may be a constraint on land productivity growth. Growth in agricultural exports and historic calorie availability had positive impacts on productivity. These latter results suggest that positive feedback effects exist between export performance and food security on one hand and agricultural productivity on the other.

Trueblood (1996) used non-parametric Malmquist index and also estimates Cobb-Douglas production function for 117 countries. The main finding of this paper is that negative productivity growth in a significant number of developing countries.

Arnade (1998) estimated agricultural productivity indices by using non-parametric Malmquist index approach for 70 countries during the years 1961-1993. He found that thirty six out of forty seven developing countries in the sample show negative rates of technical change.

Fulginiti and Perrin (1998) examined changes in agricultural productivity in 18 developing countries over the period 1961-1985. They used a nonparametric, output-based Malmquist index and a parametric variable coefficients Cobb-Douglas production function to examine, whether their estimates confirm results from other studies that have indicated declining agricultural productivity in LDCs. The results confirm previous findings, indicating that at least half of these countries have experienced productivity declines in agriculture.

Kudaligama and Yanagida (2000) used deterministic and stochastic frontiers for 43 developed and developing countries over 1960, 1970 and 1980. Their main finding of the paper is that agricultural productivity for developing countries on a per farm basis deteriorated over the time period under consideration.

Forstner et al (2001) used Data Envelopment Analysis and Malmquist TFP index to estimate productivity change over about two decades for 32 Least Developed Countries. They found that an overall decline in total factor productivity (TFP), pointing to technology as a major problem area in the growth of these countries. The study, however acknowledges that behind such decline, there seems to be ‘best-practice regresses’.

Diewert W. E. and Nakamura A. O. (2002) provided a survey of the theory and methods of the measurement of aggregate productivity as characterized by total factor productivity (TFP) and total factor productivity growth (TFPG). Index number methods are the mainstay methodology for estimating national productivity. Different conceptual meanings have been proposed for a TFPG index. The alternative concepts are easiest to understand for the case in which the index number problem is absent: a production process with one input and one output (a 1-1 process). They showed that four common concepts of TFPG all lead to the same measure in this 1-1 case. However, with only 1 input and one output it is not possible to introduce aggregation issues. To do that, they move on to a production process with two inputs (a 2-1 process). After that they present several of the commonly used index number formulas for a general N input, M output production scenario. One result demonstrated is that a Paasche, Laspeyres or Fisher index number formula provides a measure for all of the four concepts of TFPG introduced for the 1-1 case. Nevertheless, with multiple inputs and outputs, different formula choices lead to different TFPG measures. This raises the issue of choice among alternative TFPG formulas. One approach to this problem is to use algebra and economic theory restrictions to establish that certain index number formulas correspond, by Diewert's "exact" index number approach, to linearly homogeneous producer behavioral relationships that are "flexible" in the sense defined by Diewert that they provide a second order approximation to an arbitrary twice continuously differentiable linearly homogeneous function. Diewert coined the term "superlative" for an index number functional form that is exact for a behavioral relationship with a functional form that is flexible. When the exact index number approach and Diewert's numerical analysis approximation results for superlative index numbers are applied, the a priori information requirements for choosing an index number formula are reduced to a list of general characteristics of the production scenario. Additional topics discussed in this chapter include an alternative family of theoretical productivity growth indexes proposed by Diewert and Morrison, the Divisia method, and growth accounting.

Ehui and Jabbar (2002) argued that partial productivity measures are inappropriate and at times misleading for assessing the performance of agricultural production technologies and systems. This is especially true where substantial changes in resource stock and flows accompany the production process. Superlative-index based total factor productivity measures are a more appropriate technique to compare production efficiency and sustainability of alternative systems. Mathematical formulations of inter-temporal and interspatial total factor productivity measures with and without considering changes in resource stock and flows are showed by them. Then three case studies from sub-Saharan Africa in which this approach was applied are reviewed. These studies show that total factor productivity measures are biased if changes in resource stock and flows are not appropriately accounted for in inter-temporal comparisons, and differences in input intensity are not accounted for in interspatial comparisons.

Coelli, Rahman.and Thirtle (2003) applied a stochastic production frontier model to measure total factor productivity growth, technical efficiency change and technological change in Bangladesh crop agriculture for the 31 observations from 1960/61 to 1991/92, using data for 16 regions. The results reveal that technical change followed a U-shaped pattern, rising from the early 1970s, when the green revolution varieties were adopted, giving an overall rate of technical progress at 0.27 per cent per year. However, technical efficiency declined throughout, at an estimated annual rate of 0.47 per cent. The combined effect of slow technical progress, dominated by the fall in technical efficiency resulted in total factor productivity (TFP) declining at a rate of 0.23 per cent per annum, with the rate of decline increasing in the later years. TFP change is shown to depend on the green revolution technology and agricultural research expenditures.

Nin et al (2003) estimate TFP growth for 20 countries during 1961-1994 and used non parametric Malmquist TFP index with an alternative definition of technology- Sequential technology and find that the earlier results reverse and most of the developing countries experience productivity growth.

Thirtle, Lin and Piesse (2003) argued that twenty percent of the world population or 1.2 billion lived on less than $1 per day. 70% of these are rural and 90% in Asia and Sub-Saharan Africa. Research led technological change in agriculture generates sufficient productivity growth to give high rates of return in Africa and Asia and has a substantial impact on poverty, currently reducing this number by 27 million per annum, whereas productivity growth in industry and services has no impact. The per capita "cost" of poverty reduction by means of agricultural research expenditures in Africa is $144 and in Asia $180 or 50 cents per day, but this is covered by output growth. By contrast, the per capita cost for the richer countries of Latin America is over $11,000.

Trueblood and Coggins (2003) examined agricultural productivity growth over the year 1961-91 for the most comprehensive sample of countries to date by using the Malmquist index. They found that most countries showed modest productivity growth rates. Country growth rates were used to calculate weighted average regional growth rates. Globally, productivity declined during the 1960s and 1970s, but rebounded in the 1980s. The developing countries' productivity declined over the study period while developed countries exhibited positive productive growth, leading to a widening productivity gap. North America and Western Europe showed high growth while Asia and Sub-Sahara Africa showed negative growth. Reasons for the performances of different countries and regions are explored.

Kwon and Lee (2004) by using panel data on Korean rice production; parametric and non-parametric production frontiers were estimated and compared with estimated productivity. The nonparametric approach employs two alternative measures based on the Malmquist index and the Luenberger indicator, while the parametric approach was closely related to the timevariant efficiency model. Productivity measures differ considerably between these approaches. It was discovered that measures of efficiency change are more sensitive to the choice of the model than are measures of technical change. Both approaches reveal that the main sources of growth in Korean rice farming have been technical change and productivity improvements in regions of the country that have been associated with low efficiency.

Alauddin, Headey and Rao (2005) estimated total factor productivity in agriculture for 111 countries for the years 1970 to 2000. Employing this data in panel and cross-sectional regressions, the authors seek to explain levels and trends in total factor productivity (TFP) in world agriculture and also examined the relative roles of environmental and geographical factors, human capital, macroeconomic factors, technological processes resulting from globalization and the Green Revolution, and institutional factors such as measures of land inequality and proxies for urban biases in public and private expenditure. The authors conclude that, in addition to standard explanations of productivity improvements such as human capital, openness and environmental factors, both urban biases and inequality have been major impediments to successful rural development.

Coelli and Rao (2005) examined the levels and trends in agricultural output and productivity in 93 developed and developing countries that account for a major portion of the world population and agricultural output. They used data drawn from the Food and Agriculture Organization of the United Nations and our study covers the period 1980–2000. Due to the non-availability of reliable input price data, they used data envelopment analysis (DEA) to derive Malmquist productivity indices. The study examines trends in agricultural productivity over the period. Issues of catch-up and convergence, or in some cases possible divergence, in productivity in agriculture are examined within a global framework. The paper also derives the shadow prices and value shares that are implicit in the DEA-based Malmquist productivity indices, and examines the plausibility of their levels and trends over the study period.

Rae et al (2006) estimated TFP for four major livestock products in China employing the stochastic frontier approach, and decompose productivity growth into its technical efficiency (TE) and technical progress components. Efforts are made to adjust and augment the available livestock statistics. The results showed that growth in TFP and its components varied between the 1980s and the 1990s as well as over production structures. While there is evidence of considerable technical innovation in China's livestock sector, TE improvement has been relatively slow.

Tonini and Jongeneel (2006) analyzed total factor productivity (TFP) growth in agriculture for the ten Central and East European countries (CEECs) that began formal negotiations for EU accession in September 1998. A panel data set is constructed consisting of pooled time series data for the ten CEECs from 1993 to 2002, and it is used to estimate a time-varying stochastic production frontier. A Malmquist index of TFP growth is estimated and decomposed into efficiency change and technical change. The results showed that despite the fall in output, TFP growth rates were positive for all ten CEECs. This suggests that the collapse of agricultural output in the CEECs is not necessarily a good indicator of agricultural performance. An analysis that only focuses on output decline provides a partial and misleading interpretation of the success of agricultural reforms. Also, estimates of technical efficiency confirm the hypothesis that large-scale farming performs better than small-scale farming when markets are missing and economic conditions are uncertain.

Ma et al (2007) used farm-level survey data and stochastic input distance functions to make estimates of total factor productivity (TFP) on suburban dairy farms, as well as for the entire dairy sector. The results showed that over the past decade TFP growth has been positive on suburban dairy farms, and this rise in productivity has been driven mostly by technological change. However, at the same time they found that, on average, the same farms have been falling behind the advancing technical frontier. They also found one of the drivers of the suburban dairy sector is the relatively robust rate of technological change of these farms, which has been more rapid than on farms in the dairy sector as a whole. The results suggested that efforts to achieve greater adoption of new technologies and better advice on how to use the technologies and manage production and marketing within the suburban dairy sector will further advance productivity growth in the sector.

Binam, Gockowski and Nkamleu (2008) used survey data to examine the technical efficiency and productivity potential of cocoa farmers in West and Central Africa. Separate stochastic frontier models were estimated for farmers in Cameroon, Ghana, Nigeria, and Côte d'Ivoire, along with a stochastic meta-production frontier to obtain alternative estimates for the technical efficiencies of farmers in the different countries. The mean productivity potential of cocoa farmers was also estimated, by using a decomposition result applied to both the national and the meta-production frontiers. The determinants of technical efficiency were assessed to identify the reasons for differences across countries.

Kumar, Mittal and Hossain (2008) reviewed the developments in agricultural productivity related to the South Asian countries, namely Bangladesh, India, Nepal, Pakistan, and Sri Lanka. The TFP growth and its contribution in production growth have been summarized for South Asia over the past three decades. Crop-specific TFP growth figures have been updated for India by using more recent micro farm level data for three decades. A discussion and synthesis on changes in TFP and its sources of growth for the major crops, major crop systems, crops and livestock sectors for the countries of South Asia have also been presented. Methodological framework for computation of TFP and its growth has also been presented. Policies towards food secure South Asia have been outlined under the sub-heads (i) Arresting deceleration in total factor productivity, (ii) Enhancing yield of major commodities, (iii) Accent on empowering the small farmers, (iv) Environment protection, and (v) Strengthening of national agricultural research system.

Restuccia et al., (2008) argued that a decomposition of aggregate labor productivity based on internationally comparable data reveals that a high share of employment and low labor productivity in agriculture are mainly responsible for low aggregate productivity in poor countries. They used a two-sector general-equilibrium model and showed that differences in economy-wide productivity, barriers to modern intermediate inputs in agriculture, and barriers in the labor market generate large cross-country differences in the share of employment and labor productivity in agriculture. The model implies a factor difference of 10.8 in aggregate labor productivity between the richest and the poorest 5% of the countries in the world, leaving the

Asadullah and Rahman (2009) reassessed the debate over the role of education in farm production in Bangladesh using a large dataset on rice producing households from 141 villages. Average and stochastic production frontier functions were estimated to ascertain the effect of education on productivity and efficiency. A full set of proxies for farm education stock variables were incorporated to investigate the 'internal' as well as 'external' returns to education. The external effect is investigated in the context of rural neighbourhoods. Their analysis reveals that in addition to raising rice productivity and boosting potential output, household education significantly reduces production inefficiencies. However, they were unable to find any evidence of the externality benefit of schooling – neighbour's education does not matter in farm production. We discuss the implication of these findings for rural education programmes in Bangladesh.

Belloumi and Matoussi (2009) investigated the patterns of agricultural productivity growth in 16 Middle East and North Africa (MENA) countries during the period 1970 - 2000. They had used a nonparametric, output-based Malmquist index to examine whether our estimates confirm or invalidate the previous studies results indicating the decrease of agricultural productivity in developing countries. They found that on average, agricultural productivity growth increased at an annual rate of 1% during the whole period. Their estimations showed that technical change is the main source for this growth. Those results weaken as a whole the findings of the other studies, however they found a decrease in agricultural productivity mainly for developing countries suffering from political conflicts and wars. This paper fills the void of hardly any agricultural studies on MENA countries collectively, especially on productivity trends.

Hoang Viet-Ngu and T. Coelli (2009) developed a new measure of total factor productivity growth in agricultural production which incorporates environmental effects. The new measure is called the Nutrient-oriented total factor Productivity (NTFP) Index, and incorporates a materials balance condition. NTFP measures changes in nutrient-orientated efficiency and can be decomposed into efficiency change (EC), technological change (TC) and nutrient-orientated allocative efficiency change (NAEC) components. An empirical analysis, involving country-level data from OECD countries during 1990-2003, is provided using DEA methods. Estimates of mean technical and nutrient orientated efficiency are 0.798 and 0.526, respectively. Estimated mean NTFP growth is 1.5% per year, with nutrient-orientated technological progress contributing 0.8%.

Loureiro (2009) argued that agriculture is one of the most hazardous productive sectors around the world. Most previous studies have focused on health issues of farmers in developing countries, while little attention has been paid to farmers' health problems in developed countries. In this study he assessed the effect of farmers' health conditions on agricultural productivity in Norway. Employing stochastic frontier regression techniques, we conclude that differences in farmers' health help to explain the variance in agricultural production efficiency.

O'Donnell C.J. (2009) used the term *multiplicatively complete* to describe TFP index numbers that are constructed. In his earlier work he proved that, irrespective of the returns to scale and/or scope properties of the production technology, *all* multiplicatively complete TFP index numbers can be decomposed into widely-used measures of technical change and technical efficiency change, as well as unambiguous measures of scale and mix efficiency change. Members of the class of multiplicatively complete TFP index numbers include the Fisher, Tornquist and Moorsteen-Bjurek indexes, but not the popular Malmquist index of Caves, Christensen and Diewert. He used data envelopment analysis (DEA) to compute and decompose Moorsteen-Bjurek indexes of world agricultural TFP change for the period 1970- 2001. In a DEA model that prohibits technical regress, only two countries are found to maximize TFP during the study period: Nepal from 1970 to 1995 and Thailand for several years in the late 1990s. The paper explains how changes in the agricultural terms of trade have drawn other larger agricultural producers away from TFP-maximizing input-output points. The annual rate of technical progress in global agriculture is estimated to be less than 1% per annum.

Vries (2009) examined the productivity of formal and informal retailers in Brazil by simultaneously estimating a stochastic production frontier and an efficiency model for a cross-section of some 11,000 retail firms with, at most, five workers. Results showed that the efficiency of firms is positively related with ICT adoption, managerial ability, technical assistance and participation in a guild. Formal retailers are more productive than informal retailers, even after controlling for self-selection and firm, industry, and firm-owner characteristics.

Avila and Evenson (2010) computed measures of total factor productivity (TFP) growth for developing countries and then contrast TFP growth with technological capital indexes. In developing these indexes, we incorporate schooling capital to yield two new indexes: Invention-Innovation Capital and Technology Mastery. They found that TFP performance is strongly related to technological capital and that technological capital is required for TFP and cost reduction growth. Investments in technological capital require long-term (20- to 40-year) investments, which are typically made by governments and aid agencies and are the only viable escape route from mass poverty.

Fuglie (2010) examined several country-level case studies that have acquired representative input cost data to construct Tornqvist-Theil growth accounting indexes of agricultural TFP growth and apply their average cost-share estimates to other countries with similar agriculture in order to construct aggregate input indexes for these countries. For some regions for which reliable input cost data are not available (namely, Sub-Saharan Africa and the countries of the former Soviet Union), he used econometrically estimated input production elasticities as weighting factors for input growth aggregation. Theoretically, production elasticities and corresponding cost shares should be equal, so long as producers maximize profit and markets are in long-run competitive equilibrium. With growth rates in aggregate output and input thus constructed, he derived growth rates in agricultural TFP by country, region, and for the world as a whole for each year from 1961 to 2007.

Jin et al (2010) concentrated on three specific objectives. First, relying on the National Cost of Production Data Set—China's most complete set of farm input and output data—they planed the input and output trends for 23 of China's main farm commodities. Second, using a stochastic production frontier function approach we estimate the rate of change in TFP for each commodity. Finally, they decomposed the changes in TFP into two components: changes in efficiency and changes in technical change. Their main findings are especially after the early 1990s are remarkably consistent. China's agricultural TFP has grown at a healthy rate for all 23 commodities. TFP growth for the staple commodities generally rose around 2% annually; TFP growth for most horticulture and livestock commodities was even higher (between 3 and 5%). Equally consistent, we find that most of the change is accounted for by technical change. The analysis is consistent with the conclusion that new technologies have pushed out the production functions, since technical change accounts for most of the rise in TFP. In the case of many of the commodities, however, the efficiency of producers—that is, the average distance of producers from the production frontier—has fallen. In other words, China's TFP growth would have been even higher had the efficiency of production not eroded the gains of technical change. Although we do not pinpoint the source of rising inefficiency, the results are consistent with a story that there is considerable disequilibrium in the farm economy during this period of rapid structural change and farmers are getting little help in making these adjustments from the extension system.

Headey, Alauddin, Rao (2010) estimated multi-output, multi-input total factor productivity (TFP) growth rates in agriculture for 88 countries over the 1970–2001 period, with both stochastic frontier analysis (SFA) and the more commonly employed data envelopment analysis (DEA).they fgound that with SFA to be more plausible than with DEA, and use them to analyze trends across countries and the determinants of TFP growth in developing countries. The central finding is that policy and institutional variables, including public agricultural expenditure and pro-agricultural price policy reforms, are significant correlates of TFP growth. The most significant geographic correlate of TFP growth is distance to the nearest OECD country.

Hassanpour et al (2010) investigated the sources of total factor productivity (TFP) growth in rainbow trout production in Iran using data envelopment analysis (DEA). The Malmquist index is then employed to decompose the TFP growth into technical efficiency change and technological progress. They utilized panel data of 207 trout farms in the country over a 5-year period from 2003 to 2007. The results of this study revealed that TFP growth of rainbow trout farming has an increasing trend over the period at an average annual rate of 3.7%. The trend of cumulative technological change is negative and tends to be contrary to cumulative technical efficiency change. Although there was no technological change or innovation on trout farming, the technical efficiency change was found to be the sole source for TFP change, whereas the mean of technical efficiency was estimated to be about 66%. Therefore, there was still a great relative potential for increasing trout production through improvement in managerial efficiency as well as technological progress. The study suggested that Iran also has considerable room to enhance trout aquaculture's TFP growth by shifting the production frontier with adoption of new technologies and improving innovation.

Rezitis (2010) applied the Window Malmquist Index (WMI) approach to measure changes in agricultural Total Factor Productivity (TFP) for the United States and a sample of nine European countries for the period 1973 to 1993. The dataset used in this article is obtained from Ball et al. (2001). The WMI is constructed by combining Data Envelopment Analysis, window analysis with the Malmquist index approach. Furthermore, the 'Kruskal and Wallis rank test' is used for testing frontier shifts among observed periods. The article also explores the question of convergence in TFP across the countries under consideration, by testing for β- and σ-convergence, as well as for stochastic or long-run convergence. The results show wide variation in the rate of TFP growth cross countries with an average trend growth rate of 1.62%. The results indicate the presence of β-convergence but the absence of σ-convergence for the full period under consideration but the presence of both β- and σ-convergence for the sub-period 1983 to 1993. Finally, a wide spectrum of panel unit root test results support the presence of long-run convergence among the sample countries.

Shahabinejad and Akbari (2010) measured agricultural productivity growth in Developing Eight (D-8) from 1993 - 2007 by using the data envelopment analysis (DEA). The study focused on growth in total factor productivity and its decomposition in to technical and efficiency change components. It was found that, during that period, total factor productivity has experienced a positive evolution in D-8. Decomposition of TFP shows that technical change is the main source of this growth. They also found that technical efficiency change has been the main constraint of achievement of high levels of total factor productivity. The decomposition in pure and scale efficiency change showed that the cause of the low efficiency is that, these countries have not succeeded well in expanding of agriculture sector of their economy. Finally it was found that, all D-8 countries improved technology more than efficiency in the reference period.

Lee and Cheng (2011) estimated total factor productivity growth of the five ASEAN founding members by decomposing total factor productivity growth into technical efficiency and technological progress. By using the stochastic frontier model with individual-specific temporal pattern of technical efficiency for the period of 1981–2003, the present paper identifies the unique temporal pattern of productivity changes in each country, to analyze the relationship between country characteristics and the inherent efficiency and productivity changes. The empirical results indicate that over the study period, growth in Singapore and Malaysia was largely driven by both technological progress and input accumulation, whereas growth in

Thailand was induced by an improvement in technical efficiency and through input accumulation.

Rezek, Campbell and Rogers (2011) argued that accurate measures of total factor productivity (TFP) across countries can be helpful in identifying conditions, institutions or policies that promote agricultural development. In this article, we estimate TFP growth in agriculture for a panel of 39 sub-Saharan African countries from 1961 to 2007. We also develop a set of development outcome measures theoretically consistent with strong agricultural performance to serve as external validation of our results. We find that three estimation methods (stochastic frontier, generalised maximum entropy, and Bayesian efficiency) generate relative rankings that are consistent with the development outcome measures, providing external validation of the methods. However, the data envelopment analysis approach performs poorly in this regard.

Yeboah *et al* (2011) tried to determine empirically whether North American Free Trade Agreement (NAFTA) has contributed to increased agricultural productivity in any of its member countries. Implementation of the NAFTA began on January 1, 1994. This agreement removed most barriers to trade and investment among the United States, Canada, and Mexico, in which all non-tariff barriers to agricultural trade between these countries were eliminated. Data Envelopment Analysis (DEA) and the Malmquist Productivity Index were used to estimate the total factor productivity change, technical change, and efficiency change of agricultural production for each NAFTA country. Then, using time series data, the efficiency changes in countries were compared to determine whether NAFTA has been beneficial to the agricultural sector of a member country, Total factor productivity, technical change, and efficiency change of agricultural production in NAFTA countries were analyzed for the period 1980-2007, and then a comparison between pre- and post-NAFTA periods was also made. In the analysis, aggregate agricultural production was used as the output, and five variables were considered as the inputs, which included: land, labor, capital, fertilizer and livestock. The results revealed that the average annual total factor productivity increased by 1.6 percent during the 1980-2007 periods for NAFTA countries, mainly coming from technical change. Total factor productivity did not change obviously during the pre-NAFTA period. In contrast, it increased by 2.7 percent due to technical improvements in post-NAFTA period. Consequently, it is noticeable that compared to the pre-NAFTA period, the countries especially Mexico performed better by achieving higher levels of productivity in agricultural production.

Mohan and Matsuda (2013) examined the trends in major principal crop productivity growth in 10 regions in Ghana. A panel dataset is constructed for the period 2000-2009 from the Food and Agriculture Organization of the United Nations and Ministry of Food and Agriculture, Ghana database. A nonparametric data envelopment analysis (DEA) programming method is used to compute Malmquist productivity indices. These are decomposed into two component measures: efficiency change and technical change. The study examines the trends in regional level agricultural productivity growth in Ghana from 2000-2009 and for the sub-periods 2000-04 and 2005-09. The paper also indicates trends between the total factor productivity and partial productivity indices: labor productivity and land productivity. We find that the total productivity growth rate is higher in Northern region of Ghana followed by Eastern and Upper West regions. The overall contribution of technical change is greater than that of efficiency change to overall productivity changes in all the regions except Central, Eastern regions.

Hassan et al (2014) analyzed the Total Factor Productivity growth of maize using Data Envelopment Analysis (DEA) based on Malmquist Index in Nigerian. Factors that affect maize total factor productivity growth were also identified using Ordinary Least Square (OLS) method. The study used secondary annual data for the period from 1971- 2010 in order to attain the objective. The result revealed that for the forty-year period of maize production the mean value of TFP was 1.004. This implied a maize total factor productivity growth of 0.4%. In the period of study, the result showed that, the country had registered the total factor productivity growth of ≥ 1.00 that stood at 43.6%. While 56.4% of the time studied the country had a decrease in maize total factor productivity growth, and that confirmed inputs growth rather than an output growth. From 1971-1975 on average the country registered a regress in total factor productivity growth by -3.5%.However, from 1986-1990 the country had on average registered maize productivity growth of 3.7%. The result further showed that from 1991-1995 the country had on average experienced a 35.7% growth in maize productivity in the country. A double digits productivity growth of 33.4% is also exhibited for the period from 2006-2010.For the determinants of maize total factor productivity growth, research and development spending, net value of production, fertilizer price and labor were identified to have a significant influence on total factor productivity growth .It was recommended that, expanding scope of research and development, net value of production and labor use will help to raise maize productivity growth in the country. Also price of production inputs like fertilizer should be part of government policy priorities.

2.4.3 Empirical Literature Related to Estimation of TFPG in Agricultural Sector in Indian Context

There are several studies that estimated Total factor Productivity Growth of Indian Agricultural Sector. Some of the important studies mainly focusing on the recent developments are done by Dholakia and Dholakia (1993);Rosegrant and Evenson (1994); Mahadevan (2003); Kumar and Mittal (2006); Kumar, Mittal and Hossain (2008); Kannan (2011); Singh and Singh (2012); Ohlan (2013); Saha (2014); Saikia (2014); Sanap, More and Bonkalwar (2014); Olayiwola, Awasthi and Raghuwanshi (2015); Suresh and Chandrakanth (2015); Chaudhary (2016); Misra, Chavan and Verma (2016); Sanap, More and Bonkalwar (2016) among others.

Dholakia and Dholakia (1993) estimated the sources of growth of Indian agriculture for three sub-periods during 1950-51 to 1988-89. It also estimated the contribution of adverse weather conditions and intensity of resource use to total factor productivity growth. It was found that TFPG has contributed significantly to the acceleration of agricultural growth facilitating release of scarce resources from agriculture to other sectors in the economy. Thus, TFPG in agriculture has been the prime driving force behind the acceleration of overall growth in the Indian economy achieved during the eighties. The main determinant of TFPG has been found to be the use of modern inputs like fertilizer, HYV seeds and irrigation.

Kumar and Rosegrant (1994) estimated TFP growth for rice in India and they found that the TFP index has risen by around 1.85 per cent per year in the southern region, 0.76 per cent in the northern and 0.36 per cent in the eastern region.

Rosegrant and Evenson (1994) estimated total factor productivity (TFP) growth in India and examined the sources of productivity growth, including public and private investment, and estimates the rates of return to public investments in agriculture. The results show that significant TFP growth in the Indian crops sector was produced by investments -- primarily in research -- but also in extension, markets, and irrigation. The high rates of return, particularly to public agricultural research and extension, indicate that the Government of India is not over investing in agricultural research and investment, but rather that current levels of public investment could be profitably expanded.

Fan, Hazell and Thorat (1998) estimated TFP for agriculture at state-level using Tornqvist-Theil index for the period 1970-1994 and found that total factor productivity for India grew at an average annual rate of 0.69 percent between 1970 and 1995. Total factor productivity grew at a rate of 1.44 percent per annum in 70's and in 80s it grew at a rate of 1.99 percent per annum. But since 1990, total factor productivity growth in Indian agriculture has declined by 0.59 percent per annum. For Andhra Pradesh, Karnataka, Uttar Pradesh, Himachal Pradesh and Kerala the TFP varies between 0 to 1 % and in case of Punjab, Bihar, Orissa, Maharashtra, West Bengal and J&K it is greater than 1%. In case of Haryana, Madhya Pradesh, Gujarat, Assam and Rajasthan the TFP is negative.

Murgai (1999) used Tornqvist-Theil Index to estimate TFP growth in Punjab at district level during 1960-1993. TFP growth was 1.9 percent in average from 1960 to 1993 and it was found to be lowest during the green revolution years.

Forstner et al (2002) computed Malmquist TFP index using Data Envelopment Analysis to estimated productivity change over about two decades for 32 Least Developed Countries and found that an overall decline in total factor productivity (TFP), pointing to technology as a major problem area in the growth of these countries.

Mahadevan (2003) argued that the Indian agricultural sector has been undergoing economic reforms since the early 1990s in the move to liberalize the economy to benefit from globalization. She traced this process, analyses its effects on agricultural productivity and growth and discusses the problems and prospects for globalization to draw policy implications for the future of Indian agriculture.

Bhushan (2005) used Data Envelopment Analysis for estimation of Malmquist TFP index for major wheat producing states in India and found that TFP growth rate to be highest in Punjab and Haryana which is attributed to technical progress in these two states. In case of Rajasthan and Uttar Pradesh TFP growth rate is positive while in case of Madhya Pradesh it is negative. As compared to 1980s, mean growth of TFP is found to be higher in 1990s and the primary source of TFP growth is technical progress and not efficiency improvements.

Kumar and Mittal (2006) argued that the post-Green Revolution phase is characterized by high input-use and decelerating total factor productivity growth (TFPG). The agricultural productivity attained during the 1980s has not been sustained during the 1990s and has posed a challenge for the researchers to shift the production function upward by improving the technology index. It calls for an examination of issues related to the trends in the agricultural productivity, particularly with reference to individual crops grown in the major states of India. Temporal and spatial variations of TFPG for major crops of India have also been examined. They estimate TFP growth for different states in case of paddy and wheat. They find TFP of paddy has declined in Haryana and Punjab but TFP of wheat is positive for these states.

Bosworth and Collins (2008) used growth accounting approach and estimated TFP growth in primary sector for India. They found that TFP is 0.8% during 1978-2004, 1% for the period 1978-1993 and 0.5% for the period 1993-2004.

Kumar, Mittal and Hossain (2008) reviewed the developments in agricultural productivity related to the South Asian countries, namely Bangladesh, India, Nepal, Pakistan, and Sri Lanka. The TFP growth and its contribution in production growth have been summarized for South Asia over the past three decades. Crop-specific TFP growth figures have been updated for India by using more recent micro farm level data for three decades. A discussion and synthesis on changes in TFP and its sources of growth for the major crops, major crop systems, crops and livestock sectors for the countries of South Asia have also been presented. Methodological framework for computation of TFP and its growth has also been presented. Policies towards food secure South Asia have been outlined under the sub-heads (i) Arresting deceleration in total factor productivity, (ii) Enhancing yield of major commodities, (iii) Accent on empowering the small farmers, (iv) Environment protection, and (v) Strengthening of national agricultural research system. This paper would provide useful information to the people interested in doing research on these issues. Some of the concerns raised in this paper on productivity would provide direction for future research in this area.

Chand, Kumar and Kumar(2011) concluded that Productivity performance, measured by the growth in TFP, has shown a considerable variation across crops and regions. Wheat has enjoyed the highest benefit of technological breakthroughs throughout during the past three decades with its TFP growth close to 2%. Rice lags far behind wheat, while maize has achieved an annual TFP growth of around 0.67%. The major cereals, namely wheat, paddy and maize have experienced a lower growth in TFP after mid-1990s. Despite lot of claims about hybrid sorghum, its TFP has shown a decline during 1995 to 2005. In contrast, the TFP growth in bajra, which is entirely a rainfed crop, has been highly impressive.

Kannan (2011) estimated TFP of ten major crops grown in the Indian state of Karnataka and analysed its determinants. Growth accounting method of Tornqvist-Theil Index has been used for estimating TFP. The study has relied on Cost of Cultivation data published by the Ministry of Agriculture, Government of India. The study draws motivation from the lack of research evidence to show whether productivity growth in the crop sector has improved post 2000s on account of its widespread slow down or negative growth witnessed during 1980s and 1990s. The analysis confirms that most crops have registered low productivity growth across these periods. Interestingly, during 2000-01 to 2007-08 all crops have showed a positive growth in TFP. Further, the analysis of determinants of TFP indicates that the government expenditure on research, education and extension, canal irrigation, rainfall and balanced use of fertilisers are the important drivers of crop productivity in Karnataka. It is necessary that both public and private investment should be enhanced in agricultural research and technology, and rural infrastructure for sustaining productivity growth in the long run.

Singh and Singh (2012) analyzed the rate of total factor productivity growth and technical progress of Indian Agriculture between the period 1971 to 2004, using a Data Envelopment Analysis. It has been observed that that the productivity growth of Indian agriculture is negative, thus confirms that the entire output growth is contributed by input growth. The decomposition of productivity growth into efficiency change and technical progress reveals that the efficiency change is positively contributing towards the growth of productivity whereas, the negative growth of technology restrict the potential productivity growth in Indian agriculture. Further, it has also been observed that efficiency change is insignificant whereas, the technical change is of Hicks non-neutral type in Indian agriculture.

Ohlan (2013) assessed the total factor productivity (TFP) growth and efficiency levels in the Indian dairy processing industry using the Tornqvist index and data envelopment analysis (DEA) models over the period 1980-2008. He utilized a different empirical approach and extends the data sets. To examine the nature of scale inefficiency, non-increasing returns to scale DEA frontier is used. Our results suggest that total factor productivity in the Indian dairy processing industry has grown significantly. An average technical efficiency level of 72% which implies approximately a 38% inefficiency level is observed from the study. The decomposition of TFP growth indicates that growth is driven more by technical efficiency changes than by scale efficiency. Highest input slacks are observed for working capital. He note that a devaluation in terms of real effective exchange rate, profitability, export and import penetration and research stock play a significant role in explaining the productivity growth in the Indian dairy industry. The non-increasing returns to scale DEA frontier analysis suggests that on an average scale inefficiency is due to increasing returns to scale. Finally, it is noticed that in India, a high volume of milk does not reach to milk processing plants. It is suggested that for efficient utilization of existing processing capacity in dairy plants, a systematic investment is needed in logistics of raw milk collection and infrastructure development. The European model may be used as a benchmark in strengthening milk farmers for increasing farm size and building own processing capacity.

Saha (2014) attempted to estimate the aggregate Total Factor Productivity (TFP) for the Indian economy using the conventional growth accounting method. It has been observed that on an average the TFP has grown by 1.49 per cent during the study period but it is erratic in nature. Although during 1960s average the TFP growth in India was positive, it was very low and almost close to zero. Similarly, the economy experienced technological regress instead of technical progress during 1970s due to the average negative TFP growth. External shocks like war, drought, oil price-hike along with rigid rules and regulations during these periods could be the probable reasons for low productivity of the economy. However, the economy’s overall productivity has increased considerably after the initiation of internal economic reforms measures during 1980s. The economy has been experiencing continuous rise in TFP growth since the introduction of external economic reforms. The study reveals that TFP estimates in India are not sensitive to factor shares.

Saikia (2014) reviewed the different methods of measuring TFP and highlights some issues related to measurement of TFP in agriculture, especially in the Indian context. The paper also discussed the determinants of TFP growth in agriculture and analyse the trends in TFP growth in Indian agriculture. The TFP growth in Indian agriculture was very low in the pre green revolution period and it declined during 1970s. During 1980s the TFP growth rate has marginally improved, but it has again come down during the 1990s.

Sanap, More and Bonkalwar (2014) measured trends in production and Total factor Productivity growth (TFP) of sugarcane crop in sub-sector of Maharashtra State. The compound growth rates and Cuddy Della instability index were used for studying trends and the Tornquist-Theil hained Divisia index approach was applied for the measurement of total factor productivity using output and input data of sugarcane crop. Farm-level data on yield, level of inputs use and their prices for the period 1989-90 to 2008-09 were collected from the state funded cost of cultivation scheme. The multi-variable model was estimated to know the determinants of total factor productivity growth by assuming total factor productivity as dependent variable. Beside double sown area, other explanatory variables include total amount of loan, net cropped area, area under irrigation, area under high yielding variety, annual rainfall, and villages electrified, number of tractors, number of pump sets and road density. The results indicated that though area and production of sugarcane crop increased, productivity growth was very less in Marathwada as well as in Maharashtra region. There was no substantial growth recorded in sugarcane output in the region. Use of chemical fertilizers viz. nitrogen, phosphorous, potash and number of irrigations increased by 1.53%, 2.92%, 11.33% and 10.92% respectively in the region. Use of other inputs fluctuated around some constant mean value over the period. There is growth in total factor productivity of sugarcane crop of sub-sector in Maharashtra state. Area under irrigation, area under high yielding varieties, number of tractors and road density had positive and significant impact on total factor productivity of sugarcane crop in Maharashtra.

Olayiwola, Awasthi and Raghuwanshi (2015) estimated total factor productivity for principal crops in Madhya Pradesh using time series secondary data on area, production productivity of major crops in Madhya Pradesh. The Malmquist model is selected over Tornqvist model for the study because of stationality and redundancy problem associated with time series. Structural changes occurred in area and production of principal crops during the specific period of time due to policy effect and autonomous production as well. The variability in the total outputs and total inputs index was due to exploitation of available production potential in the state. Malmquist total factor productivity index explained the stages of production in Madhya Pradesh over periods of time. Post global and combine periods were better as compared with pre global period. Total factor productivity is a comprehensive measure of productivity and has gained acceptance among government officers, policy makers, productivity specialist and economist.

Suresh and Chandrakanth (2015) used the time series data on cost of cultivation of ragi. By Tornqvist Theil index of TFP they estimated TFP growth and by regression analysis they identified the sources of TFP growth. The result indicated that The Total Factor Productivity index of ragi grew at 4.75 per cent per annum. Public research significantly contributed to TFP growth in ragi. The additional investment of one rupee in ragi research generated additional income of Rs. 26.84, indicating substantial rate of returns to investment on research in ragi in Karnataka.

Chaudhary (2016) estimated changes in state-level agricultural TFP for 1983-2006 using non parametric Sequential Malmquist TFP index and decomposes TFP change into technical efficiency change and technical change. Productivity improvements and technical change are found to be marked in very few states of India. Efficiency improvements are observed to be low for most of the states; efficiency decline observed in several states implies huge production gains are possible even with existing technology. To improve TFP, it is imperative to increase efficiency levels as well as achieve a more even spread of better technology.

Misra, Chavan and Verma (2016) attempted to explore the relationship between agricultural credit and agricultural production/productivity. The state-level panel model attempted in this article suggests a positive impact of the intensity of agricultural credit on total factor productivity in agriculture. The impact was relatively stronger with respect to direct agricultural credit. A case study of the (combined) state of Andhra Pradesh also suggests a positive association between agricultural credit and agricultural production. The study lends credence to the policy approach of including agriculture, the largest employer in the Indian economy, as a sector for priority credit in India. It also highlights the point that the sector deserves continued policy support in order to move onto a sustainable and higher growth path.

Sanap, More and Bonkalwar (2016) measured total factor Productivity growth of pigeon pea crop in sub-sector of Maharashtra State. The Tornqvist Theil chained Divisia index approach was applied for the measurement of total factor productivity using output and input data of pigeon pea crop. Farm-level data on yield, level of inputs use and their prices for the period 1989-90 to 2008-09 were taken from the state funded cost of cultivation scheme. The multi-variable model was utilized to know the determinants of total factor productivity growth taking total factor productivity as dependent variable. Beside double sown area, other explanatory variables included total amount of loan, net cropped area, area under irrigation, area under high yielding variety, annual rainfall, villages electrified, number of tractors, number of pump sets, road density. The results indicated that total factor productivity growth was positive in pigeon pea crop in sub sector of Maharashtra State. Area under irrigation, area under high yielding varieties, rainfall, and road density has positive and significant impact on total factor productivity of pigeon pea crop in sub-sector.

2.5 Connection of the Present Study with the Existing Literature

The perusal of the literature suggests that not much attempt has been made to analyze the problems of growth, volatility and productivity of Indian agriculture at disaggregated crops level. So, the analysis of the agricultural sector at state level as well as crops level is very essential both from the academic point of view as well as policy perspective.

Given the vast development of agricultural sector in India, it will be interesting to address the issue of crop level development of different states. For successful implementation of the Millennium Development Goals, crop specific studies are extremely vital taking into account different indicators like growth, the extent of volatility and total factor productivity growth. Such study will highlight the crops for which these performances are satisfactory in comparison with the crops for which these performances are lacking and accordingly appropriate policies can be framed in order to boost up the weekly performed crops. Moreover, since in the Indian context climate condition varies crop-to-crop and from region-to-region, in order to have a good implementation of the crop wise study one must incorporate the state wise study as well because the performance of the crops varies among different states.

Thus it will be interesting to extend the literature by addressing the following important issues in the context of agricultural sector in India for different crops:

(i) To analysis the growth performance for different crops. Such an analysis will be meaningful and helpful for identifying the crops for which the growth performance is not satisfactory and thus proper measure can be taken for promoting growth for those crops whose performance are lacking.

(ii) Estimation and analysis of volatility of output prices of different crops is very much important because it identifies the crops whose output price is volatile. Now in agriculture it is well known that agricultural supply is very much dependent of its previous year's price. So, if output price is volatile then it will affect the supply decision of the farmers. Thus, it will be an interesting study to indentify the crops whose output price is more volatile so that government can take suitable measures to reduce the volatility. In Indian context it is observed that for each of the crops there exists different types of variety. Thus it will be interesting to consider the different variety in explaining the extent of price volatility. Further it is also possible that the return of each variety varies and in that case it will be interesting to find out which variety brings us more return.

(iii) Estimation and analysis of Total Factor Productivity Growth (TFPG) in agricultural sector for different crops level by applying non-parametric method of DEA analysis by using Biennial Malmquist Index (BMI) and find out the main determinants of TFPG, since as far as our knowledge goes; there is a lack in the literature highlighting this area and methodology. It is also be interesting to decompose total factor productivity growth into the component of technology change, efficiency change and scale efficiency change and hence to find out the relative importance of these components in explaining the movement of TFPG.

These are the important aspects that the present thesis seeks for attention in the context of agricultural sector in India. The contributions to the literature regarding each of these problems are discussed elaborately in the specific chapter dealing with the problems.

Chapter 3

Analysis of Growth

3.1 Introduction

Agriculture has shaped the thought, the outlook, the culture and the economic life of the people of India for so many centuries. Agriculture will continue to be central to all strategies for planned socio-economic development of the country. Therefore rapid growth of agriculture is essential not only to achieve self-reliance at national level but also for household food security and to bring about equity in distribution of income and wealth resulting in rapid reduction in poverty levels.

Indian agriculture is in the hands of millions of peasant households, mostly having tiny land holdings with preponderance of owner cultivation. In the production and investment decisions of the farmers the government has little control but the government does influence the legal, material and economic environment in which farmers operate. Although there is tremendous progress in irrigation potential in the country still two third of area under cultivation is unirrigated and there is thus heavy dependence on rainfall. Irrigated areas have experienced sharp increase in productivity level. On the other hand, productivity in unirrigated areas has remained either stagnant or experienced very small growth and most of the farmers in such areas produce for subsistence purpose. At overall level, agricultural growth remained slow and which is around 0.91% in 2012-13 in the country. Apart from that, agricultural growth remained confined to a few well endowed pockets which have created regional disparities (Vaidyanathan 1996). There is a close association between agricultural policy followed in the country and the magnitude and sources of output growth (Vaidyanathan 1996).

The measurement of growth of agriculture production involves a number of issues like the choice of period, the selection of cut-off points for different sub-periods, estimation of growth parameters and proper interpretation of results. These points have been taken up in a number of studies made earlier (**Sen**, 1967; **Narain**, 1977; **Rudra**, 1982; **Reddy**, 1978; **Das**, 1978; **Srinivasan**, 1979; **Vidyyanathan**, 1980; **Dandekar**, 1980; **Ray**, 1983; **Sawant**, 1983; **Dev**, 1887; **Boyce**, 1987; **Saha** and **Swaminathan**, 1994; **Sawant** and **Achuthan**, 1995; **Bhalla** and **Singh**, 1997, etc.).

The perusal of the empirical literature on growth suggests some limitations.

Majority of the growth analysis relied upon the assumption of deterministic trend (assuming means and variances are well defined constants and independent of time) and hence they are devoid of testing for difference or trend stationarity using unit root of modern time series approach and they tried to find a trend equation and then compare the trend between two period (with some exceptions such as Mukhopadhyay and Sarkar, 2001; Ghose and Pal, 2007; Sengupta, Ghose and Pal, 2009; Pal and Ghose,2012; among others). But those assumptions are not always valid as the series may be non stationary in nature as pointed out by researchers over the last three decades or so. Thus for getting a valid result, stationary properties of the series are to be checked.

However, the literature on the modern econometric time series analysis suggests that the growth process must be determined by the statistical properties of the series, and the break point of the series must be endogenously determined. In the presence of structural break, the standard Unit Root test is inconsistent against Trend Stationary Process[1] (TSP) (Perron, 1989). Perron (1989), in presence of one-time exogenous structural break in the series, suggested a method appropriate for testing Unit Root. Zivot and Andrews (1992) pointed out that Perron's procedure is not an appropriate one and argued that the break point should be endogenously determined rather than exogenously determined. However according to Sen (2003), the power of Zivot and Andrews (1992) test statistic is low and Sen (2003) recommended some methods to improve the power of the test.

Mukhopadhyay and Sarkar(2001) used structural break of modern time series specification technique to test for acceleration in food grains production in West Bengal and found that there exists a negative effect on the level of food grains production in West Bengal, taking 1982-83 as break point. They also found that the underlying series is a Different Stationary (DS) series with drift implying that one cannot claim for the existence of a deterministic trend in the level of food grains production. However, their analysis is based on overall West Bengal economy. But West Bengal's agricultural production shows a great variability due to variability in land capacity, climate, fertilizer uses, irrigated area etc. from district to district. As a result one may not get a uniform growth rate for all the districts. Ghose and Pal (2007) measured inter-district disparity in growth of food grains production in

[1] A TSP implies that the effect of random shock is temporary around a stable trend.

West Bengal by applying both the exogenous and endogenous structural break analysis to test for acceleration in food grains production. In case of exogenous structural break analysis the impact of liberalization policies was analysed by taking 1991-92 as the break point. Sengupta, Ghosh and Pal (2009) considered the interstate variation of food grains, non food grains and total agricultural production by considering exogenous structural break due to Perron and endogenous structural break due to Zivot and Andrews. The limitation of Sengupta, Ghosh and Pal (2009) was that endogenous structural break analysis was carried out by using Zivot and Andrews, whoes power of the test is low (Sen, 2003). Such limitations was rectified by Sen(2003). Mukhopadhyay and Sarkar(2001) and Ghosh and Pal(2007) although considered modern time series approach they did not considered the crop-wise study for the case of Indian economy as a whole. Pal and Ghose (2012) used Sen's approach for finding out structural break of agricultural output for different districts of West Bengal. However, a crop-wise study of the Indian agricultural sector using this modern time series approach is still lacking. The need for analyzing the crop-wise study can be justified on the following ground.

There is a significant departure from the past in 1991when Government introduced process of economic reforms, which involved deregulation, reduced government participation in economic activities and liberalization. Though much of the reforms were not initiated to directly affect agriculture sector, the sector was affected indirectly by devaluation of exchange rate, liberalisation of external trade and disprotection to industry. Then came new international trade accord and WTO, requiring opening up of domestic market. Although initially there was positive impact of trade liberalisation on Indian agriculture but afterwards it became real threat for several commodities produced in the country. All these changes raised new challenges and provided new opportunities that required appropriate policy response. Besides, last two decades had only experienced limited price intervention and there was a sort of policy vacuum. Because of this, there was a strong pressure on the government to come out with agriculture policy as required to provide new direction to agriculture in the new and emerging scenario. In response to this, government of India announced New Agricultural Policy in July 2000. One of the salient features of new agricultural policy is that it aimed over 4% annual growth rate over the next two decades.

Therefore, for successful implementation of the New Agricultural Policy the study on individual crops is extremely urgent. Such study will highlight the crops for which the growth of output are satisfactory vis-a-vis the crops for which these performance are lacking. The study of the growth pattern of major crops and to find out the suitable break point on the growth process is essential given the changed scenario in Indian Agricultural Sector. At the same, time given the fact that there exists high degree of inter-state variation due to land capacity, climate, fertilizer uses, irrigated area etc. one may not get the uniform pattern of growth rate of any particular crop for different states of India. Hence there is also need to analyse the inter-state variation of each crop. Such analysis becomes helpful for policy formulation for improving growth performance for different crops. It is also needed to know whether the growth process converges or not. Side by side it is important to analysis what are the major factors that determine the growth of output.

Given this background, **the objectives of the present chapter** are **first of all** to check whether the series of output of major selected crops and states converges to a path having trend preserving properties or not without the presence of structural break. **Secondly,** if there exists one structural break in the series then to check whether the series of output of major selected crops and states converges to a path having trend preserving properties or not using Sen (2003) method. **Thirdly,** to analyze the growth pattern of output for the major selected crops and states**.** Depending on the estimated results of Sen (2003) about the growth performance of output, the major selected crops and states will be classified into different groups and intercrops and interstate comparison is made. **Fourthly,** to test for the presence of multiple structural breaks in the series for the major selected crops and states by using Bai and Perron (1998, 2003) method.

The major selected crops and sates are as follows:

A. **Food crops:** Rice, Wheat, Maize, Jowar, Gram, Bajra.
   For each of the crop we will consider the major states producing these crops.

- ✓ Rice- Andhra Pradesh (AP), Assam (AS), Biha (BI), Haryana (HA), Karnataka (KA), Madhya Pradesh (MP), Orissa (OR), Punjab (PU), Tamil Nadu (TN), Uttar Pradesh (UP), West Bengal (WB).
- ✓ Wheat- Bihar (BI), Haryana (HA), Madhya Pradesh (MP), Rajasthan (RA), Punjab (PU), Uttar Pradesh (UP).
- ✓ Maize(Corn)- Andhra Pradesh (AP), Bihar (BI), Gujarat (GU), Himachal Pradesh (HP), Karnataka (KA), Madhya Pradesh (MP), Punjab (PU), Uttar Pradesh (UP), Rajasthan (RA).

- ✓ Jowar(Sorghum)- Andhra Pradesh (AP), Gujarat (GU), Karnataka (KA), Maharashtra (MA), Rajasthan (RA), Tamil Nadu (TN), Uttar Pradesh (UP).
- ✓ Gram- Bihar (BI), Haryana (HA), Madhya Prades (MP), Maharashtra (MA), Rajasthan (RA), Uttar Pradesh (UP).
- ✓ Bajra(Peari Millets)- Gujarat (GU), Haryana (HA), Karnataka (KA), Maharashtra (MA), Rajasthan (RA), Uttar Pradesh (UP).

B. **Cash crops or Non Food Crops:** Cotton, Groundnuts, Rapeseed/Mustard Oil. Again for each of the crop we will consider the major states producing these crops.

- ✓ Cotton- Andhra Pradesh (AP), Gujarat (GU), Haryana (HA), Karnataka (KA), Madhya Pradesh (MP), Maharashtra (MA), Punjab (PU), Rajasthan (RA).
- ✓ Groundnuts- Andhra Pradesh (AP), Gujarat (GU), Karnataka (KA), Madhya Pradesh (MP), Tamil Nadu (TN).
- ✓ Rapeseed/Mustard Oil- Assam (AS), Gujarat (GU), Haryana (HA), Madhya Pradesh (MP), Rajasthan (RA), Uttar Pradesh (UP), West Bengal (WB).

The study period is from 1970-71 to 2013-14

Finally, after determining the growth rate, break points etc. it is important to identify the reasons behind the variation in growth of output.

Now, as we have considered different major producing states under each crop so for analyzing the determinant of growth rate we need to construct a panel model for each of the crop. Further, while considering the determinant for growth it is found that there exist some explanatory variables which in turn depends on the dependent variable, ie. growth of output. For example in the present case one of the explanatory variable taken for growth of output is the growth of HYV uses which in turn depends on the growth of output. Thus in order to explain the growth of output, one need to formulate a simultaneous equation kind of frame work in the panel setup showing two way dependency between the dependent variable and the explanatory variable. **Thus, for estimating the suitable determinants this chapter uses simultaneous panel regression analysis under seemingly unrelated regression (SUR) framework and adjusted for contemporaneous correlation (across units) and cross section heteroscedasticity. This chapter also considers all the regressions in the growth**

terms. That is growth of dependent variable is regressed on the growth of the different explanatory variables.

Section 3.2 discusses the methodology and data source. In **subsection 3.2.1** the methodology for testing the presence of unit root is described. **Subsection 3.2.2** describes the methodology of studying the growth performance of the major selected variables using Sen (2003) approach of endogenous structural break and the methodology of comparison of different crops and states on the basis of their performance. **Subsection 3.2.3** presents the method for analyzing multiple structural breaks using Bai-Perron method. and in **subsection 3.2.4** the methodology of simultaneous panel method for finding out the major determinants of growth is discussed. Data Sources are discussed in **3.2.5**. **Section 3.3** presents the Results of estimation and **Section 3.4 concludes.**

3.2 Methodology and Data Source

3.2.1 Methodology for Testing the Presence of Unit Root

The methodology can be discussed in three stages. In the first stage the method of testing unit root by applying Augmented Dickey-Fuller (ADF) is carried out. Second stage deals with the method proposed by Phillips and Perron (1988) (PP) for testing unit root and in the third stage one can find out the method suggested by the Kwiatkowski, Phillips, Schmidt and Shin (1992)(KPSS) for testing the unit root. For practical application Kwiatkowski et. al. (1992) suggested that ADP or PP test should be applied first and then the KPSS test should be used as a confirmatory test. The idea behind this reason is that if a series is stationary then the ADF or PP test should reject the nonstationarity null whereas the KPSS test should not reject its null hypothesis of that series being a stationary process.

Augmented Dickey-Fuller (ADF) Test

A major debate concerning the nature of macroeconomic data has been going on until **Nelson** and **Plosser (1982)** published their seminal work. They found that underlying process is Difference Stationary (hereafter, DSP) rather than Trend Stationary (hereafter, TSP). A TSP process implies that the effect of random shock is temporary around a trend. On the other hand, DSP process implies that this random shock has a permanent effect. Further, in case of DSP process the variance or the higher order moments of Y_t is not constant. It is dependent on time. After their work a large number of studies also suggested that DSP process is the most appropriate one.

The test for detecting whether a series is DSP or TSP is called the unit root test, as introduced by Dickey and Fuller (1979, 1981). To understand these processes consider the following regression equation:

$$\Delta y_t = \delta_0 + \delta_1 t + \gamma y_{t-1} + u_t \qquad where \;\; u_t = \alpha u_{t-1} + \varepsilon_t$$

A test of null hypothesis $H_0 : \gamma = 0$ is required against the alternative hypothesis $H_1 : \gamma < 0$.

If the null hypothesis is failed to reject then the underlying series is DSP. Rejection of the null hypothesis implies the underlying series is TSP. The coefficient of Y_{t-1} does not follow the standard t distribution. The problem was solved by Fuller, who obtained the limiting distribution of this coefficient. These distributions were approximated empirically by **Dickey (1976)**. **MacKinnon (1990)** has derived critical values from a much larger set of replications. If the underlying process is TS and the coefficient of time is statistically significant then it implies that there exists a trend in the series. And if constant term is statistically significant then there exists a drift in the model. Now if ΔY_t depends on the ΔY_{t-j} (where j=1, 2, K, K<T) then the above test procedure is called as Augmented Dickey Fuller (ADF) test. The ADF test is based on estimating the following regression:

$$y_t = B^{/} D_t + \gamma y_{t-1} + \sum_{j=1}^{p} \delta_i \Delta y_{t-j} + \varepsilon_t$$

Where D_t is a vector of deterministic terms (constant, trend etc.). The p lagged difference terms,Δy_{t-j}, are used to approximate the ARMA structure of the errors, and the value of p is set so that the error ε_t is serially uncorrelated. The error term is also assumed to be homoscedastic. The specification of the deterministic terms depends on the assumed behaviour of y_t under the alternative hypothesis of trend stationarity as described in the previous section. Under the null hypothesis, y_t is I(1) which implies that γ = 1.

An alternative formulation of the ADF test regression is

$$\Delta y_t = B^{/} D_t + \pi y_{t-1} + \sum_{j=1}^{p} \delta_i \Delta y_{t-j} + \varepsilon_t$$

The ADF unit root test checks the null hypothesis $H_0 \colon \pi = 0$ against the alternative hypothesis $H_1 \colon \pi < 0$; it is based on the t-statistic of the coefficient π from OLS estimation of the above equation. The ADF test statistic does not follow an asymptotic standard normal distribution under H_0 but it has a non standard limiting distribution. Further, this non standard limiting distribution under the unit root null hypothesis is the same as the Dickey-Fuller distribution. So, the same critical values corresponding to the Dickey-Fuller test are applicable for the ADF test as well.

Phillips and Perron (PP) Test

Phillips and Perron (1988) developed a number of unit root tests that have become popular in the analysis of financial time series. This test is a modification of the original Dickey-Fuller test statistic using nonparametric approach. This test which should ideally be called a semi parametric test since it considers the usual parametric regression but treats serial correlations of the error term in nonparametric way. The test regression for the PP tests is

$$\Delta y_t = B^{/} D_t + \pi y_{t-1} + u_t$$

Where u_t is I(0) and may be heteroscedastic. The PP tests correct for any serial correlation and heteroskedasticity in the errors u_t of the test regression by directly modifying the test statistics $t_{\pi=0}$and$T\hat{\pi}$. These modified statistics, denoted Z_t and Z_π, are given by

$$Z_t = (\frac{\hat{\sigma}^2}{\hat{\lambda}^2})^{\frac{1}{2}} . t_{\pi=0} - \frac{1}{2}\left(\frac{\hat{\lambda}^2 - \hat{\sigma}^2}{\hat{\lambda}^2}\right) . (\frac{T.SE(\widehat{\pi})}{\hat{\sigma}^2})$$

$$Z_\pi = T\hat{\pi} - \frac{1}{2}\frac{T^2.SE(\widehat{\pi})}{\hat{\sigma}^2}(\hat{\lambda}^2 - \hat{\sigma}^2)$$

The terms $\hat{\lambda}^2$ *and* $\hat{\sigma}^2$ are consistent estimates of the variance parameters

$$\sigma^2 = \lim_{T\to\infty} T^{-1} \sum_{t=1}^{T} E[u_t^2]$$

$$\lambda^2 = \lim_{T\to\infty} \sum_{t=1}^{T} E[T^{-1}S_T^2]$$

Where $S_T = \sum_{t=1}^{T} u_{t.}$

The sample variance of the least squares residual $\hat{u}_t$is a consistent estimate of σ^2, and the Newey-West long-run variance estimate of u_t (using $\hat{u}_t$ is a consistent estimate of λ^2). Under the null hypothesis that π = 0, the PP Z_t and Z_π statistics have the same asymptotic distributions as the ADF t-statistic and normalized bias statistics. One advantage of the PP tests over the ADF tests is that the PP tests are robust to general forms of heteroskedasticity in the error termu_t. Another advantage is that the user does not have to specify a lag length for the test regression.

Kwiatkowski, Phillips, Schmidt and Shin (KPSS) Test

In case of both ADF and PP test the null hypothesis is taken to be a unit root and the alternative hypothesis is stationary. The test proposed by Kwiatkowski, Phillips, Schmidt and Shin (1992), takes a different view of the unit root testing problem by taking stationarity as the null against an alternative of a unit root, i.e., $H_0: y_t \sim I(0)$ against $H_1: y_t \sim I(1)$. They derive their test by starting with the model

$y_t = B^{/} D_t + \mu_t + u_t$

$u_t = \mu_{t-1} + \varepsilon_t$ Where $\varepsilon_t \sim WN(0, \sigma_\varepsilon^2)$

Where, D_t is the deterministic components (constant or constant plus time trend) and $u_t$is stationary and may be heteroskedastic. Notice that u_t is a pure random walk with innovation varianceσ_ε^2. The null hypothesis that $y_t \sim I(0)$ is formulated as $H_0 : \sigma_\varepsilon^2 = 0$, which implies that u_t is a constant. The KPSS test statistic is the Lagrange multiplier (LM) or score statistic for testing $\sigma_\varepsilon^2 = 0$ against the alternative that $\sigma_\varepsilon^2 > 0$ and is given by

$$KPSS = \frac{(\frac{1}{T^2} \sum_{t=1}^{T} \widehat{S_t^2})}{\widehat{\lambda^2}}$$

Where $\widehat{S_t^2} = \sum_{j=1}^{t} \widehat{u_j}$,$\widehat{u_j}$is the residual of a regression of y_t on D_t and $\widehat{\lambda^2}$ is a consistent estimate of the long-run variance of u_t using $\widehat{u_t}$. Under the null that y_t is I(0), Kwiatkowski, Phillips, Schmidt and Shin show that KPSS statistic converges to a function of standard Brownian motion that depends on the form of the deterministic terms D_t but not their coefficient values β. The critical values of the KPSS test statistic can be found in Kwiatkowski et al. (1992).

3.2.3 Methodology for Testing the Unit Root under the Presence of Structural Break using Sen (2003) approach of endogenous structural break

Perron (1989) in his path breaking work showed that the standard unit root test is not consistent against TSP in the presence of structural break and has suggested a procedure for testing unit root in presence of one time structural break in the series. The structural break is assumed to be exogenously determined from consideration of visual examination of the plots of the data. Zivot and Andrews (1992) criticized Perron's procedure for finding out the break point, as it was based primarily on visual inspection of data and further argued that the break point should be endogenously determined (rather than exogenously determined, Perron (1989)) and can be evaluated by applying OLS considering models as follows:

Model A: $$Y_t = a^A + b^A DU_t + c^A t + d^A Y_{t-1} + \sum_{j=1}^{k} \delta_j Y_{t-j} + e_t \quad (3.1)$$

Model B: $$Y_t = a^B + g^B DT_t + c^B t + d^B Y_{t-1} + \sum_{j=1}^{k} \delta_j Y_{t-j} + e_t \quad (3.2)$$

Model C: $$Y_t = a^C + b^C DU_t + c^C t + g^C DT_t + d^C Y_{t-1} + \sum_{j=1}^{k} \delta_j Y_{t-j} + e_t \quad (3.3)$$

e_t is the error term in the model and is assumed to be independently and identically distributed random variable with zero mean and constant variance i.e. $e_t \sim$ iid $(0, \sigma^2)$.

Here **Model A** permits an endogenous break in the level of the series, **Model B** allows an endogenous break in the rate of growth & **Model C** permits an endogenous break both in the level as well as rate of growth.

The dummy variables of the three models can be defined as under:

$DU_t = 1$ if $t > T\lambda$

$= 0$ otherwise

$DT_t = t - T\lambda$ if $t > T\lambda$

$= 0$ otherwise

Here T stands for total time period and T_B is the break point

Then, $\lambda = T_B/T$ is the break fraction and ranges from 2/T to T-1/T

According to Zivot and Andrews (1992), out of the (T-2) regressions, that year is chosen as break year which gives the minimum value of 't' statistics corresponding to the coefficient of Y_{t-1}. In addition to it, that model is chosen as the best fitted one which gives the minimum 't' value of the coefficient of Y_{t-1}. After finding out the best fitted model and the break point, to test for the hypothesis d^i=1, i=A, B and C i.e. coefficient of Y_{t-1} is equal to one and to compare it with the critical values given by Zivot and Andrews (1992) to determine the nature of the series (TSP or DSP).

Sen (2003) criticized the Zivot and Andrews (1992) conventional Unit Root procedure and argued that it may suffer from power distortion. Three types of characterizations are there in Zivot and Andrews (1992) namely Crash Model, Changing Growth Model and Mixed Model-of the form of break under the alternative of TSP. For all the three characterizations of the alternative, minimum t-statistics are used to test for a Unit Root, when the location of break is unknown (assuming endogenous structural break). Sen (2003) argued that since the form of break is treated as unknown, the appropriate alternative should be the Mixed Model. When the form of break is wrongly specified, there are serious implications for the power of the minimum t-statistics. Simulation suggests that Crash Model (Changing Growth Model) minimum t-statistics fail to reject the Unit Root null hypothesis, provided that the break occurs according to the Changing Growth Model (Crash Model). Some loss of power is also found for Mixed Model minimum t-statistics, when the break occurs following the Crash Model or Changing Growth Model. Thus Sen (2003) applied his test on the Mixed Model which simultaneously allows for a break in the level as well as rate of growth and test for the existence of endogenous structural break (expression for Model C-equation (3.3)). The test statistic used by Sen (2003) is SupWald statistic, originally put forth by Murray (1998) and Murray and Zivot (1998). It actually gives the joint null hypothesis of a Unit Root with no break in the intercept and the slope of the trend function. To calculate the maximum F-statistic for the null hypothesis, Sen (2003) applied the F-statistic in accordance with

$$F_T^{Max} = Max_{T_b \in \{[\lambda_0 T],[\lambda_0 T]+1,....,T-[\lambda_0 T]\}} F_T(T_b)$$

Here T_B is the break point which is a constant fraction of the sample size T i.e. T_B = $\lambda^C T$ with the current break fraction $\lambda^C \in (0,1)$ and the smallest integer function.

Thus Sen (2003) suggested the Mixed Model (Model C) having higher power than either Model A or Model B and also the F-statistic for testing the Unit Root hypothesis being more powerful than the traditional t-statistic and the power of F-statistic is more or less consistent. After getting the maximum F-statistic amongst the alternative regression equations, the estimated F-statistic ($F_T^{\max}$) is compared with the asymptotic critical values of $F_T^{\max}$ given by Sen[2]. Finally by analyzing the nature of series, conclusion can be drown whether the series follows TSP or DSP.

While estimating equation 3.3 (Model-C) logarithms of the dependent variables are taken as regressands and thus c^i i.e the coefficient of time (in Model C) represents growth rate. The growth rates obtained can provide a performance report of different crops and different states over the sample period 1970-71 to 2013-14 with respect to the growth of output and thus helps to identify the better and the worse performing states. Now from the model C, one can get the statistical significance of **DU_t** (Post Break Dummy in the Level), **DT_t** (Post Break Dummy in the Growth) and **t** (Overall Trend in the series). Now **Positive/negative DU_t (Sig)** implies increase/decrease in the level of the series at the break point. **Positive/negative DT_t (Sig) implies change** (increase/decrease) in growth rate after the break point and **Positive/negative t (Sig)** implies Deterministic Trend (Positive/negative) for the entire sample period. Now on the basis of the sign and the statistical significance of **DU_t , DT_t** and **t** the performance of different crops across the states can be classified into three categories**, i.e , Good Performer, Moderate Performer** and **Bad Performer.** The criterion of the Good Performer, Moderate Performer and Bad Performer crops are given in Table 3.19.

[2] "On Unit-root Tests when the Alternative is a Trend-break Stationary Process", Journal of Business and Economic Statistics, January 2003, Vol. 21, No. 1, pp. 174-84 and corresponding table is Table 1, page 177.

3.2.3 Methodology for Testing the Presence of Multiple Structural Break

Most of the studies related to structural change have considered the presence of one time structural break only (Perron (1989); Zivot and Andrews (1992) etc**).** But the macroeconomic time series may contain more than one structural break. Thus it is better to consider more than one structural break for analysis. In their path breaking work Bai and Perron (1998) provided a comprehensive analysis of several issues in the context of multiple structural change models and develop some tests that allow inference to be made about the presence of structural change and the number of breaks. This test is helpful in the changes present and also it endogenously determines the points of break with no prior knowledge.

The method of finding out multiple structural break due to Bai-Perron consists of three steps. In the **first step** one has to check whether the underlying process is stationary or not. After checking the stationarity properties of the series, in the **second step** one has to test whether the deterministic trend process is statistically significant or not. After finding out the significant deterministic trend in **third step** one can apply multiple structural breaks analysis suggested by Bai and Perron (1998, 2003). The details of these steps are as follows:

Step-I: To find out the stationary property of the series unit root is applied. The present chapter uses three alternative tests a) Augmented Dickey-Fuller (ADF) Test, b) Phillips and Perron (PP) Test and c) Kwiatkowski, Phillips, Schmidt and Shin (KPSS) Test available in the literature. The methodology of these three tests has already been discussed in sub section 3.2.1

Step-II: In this step, two one has to check whether there exists any deterministic trend in the series or not. For this purpose one has to consider whether the coefficient of time arising in the above three tests is significantly different from zero or not. If the coefficient of time is significantly different from zero then one can conclude that there exists a deterministic trend in the series.

Step-III: After finding out the deterministic trend in the series one can now apply Bai-Perron Methodology for finding-out the multiple structural breaks. Now, there are two parts in the Bai-Perron methodology. In the **first part** we have to identify whether there exists at all any break in the series or not. Bai-Perron mentioned this test as Structural Stability versus an Unknown Number of Breaks. In the **second part**, if at least there exists any break then we have to test the presence of multiple structural breaks in the series. Bai-Perron called this test as Sequential Test.

To carry out the first part of this step-III, Bai-Perron(1998) consider the following linear regression with m breaks (m+1 regimes):

$$y_t = x_t' \beta + z_t' \delta_j + \mu_t, t = T_{j-1}, \ldots\ldots T$$

(j=1,……,m+1, T_0=0 and T_{m+1}=T)

where y_t is the observed dependent variable, $x_t \in \Re^p$ and $z_t \in \Re^q$ are vectors of covariates, β and δ_j are the corresponding vectors of coefficients with $\delta_i \neq \delta_{i+1} (1 \leq i \leq m)$ and μ_t is the error term at time t. The break dates (T_1,….,T_m) are explicitly regarded as unknown. It may be noted that this is a partial structural change model insofar as β doesn't shift and is effectively estimated over the entire sample. Then the purpose is to estimate the unknown regression coefficients and the break dates, that is to say (β, δ_1 ,…… δ_{m+1}, T_1,….,T_m), when T observations on (y_t ,x_t, z_t) are available.

Bai and Perron (1998) built a method of estimation based on the least square principle. For an m-partition (T_1,….,T_m), denoted by {T_j}, the associated least square estimator of δ_i is obtained by minimizing the sum of squared residuals

$$\sum_{i=1}^{m+1} \sum_{t=Ti-1}^{Ti} [y_t - x_t' \beta + z_t' \delta_j]^2$$

under the constraint $\delta_i \neq \delta_{i+1} (1 \leq i \leq m)$. Let $\hat{\delta}(\{T_j\})$ be the resulting estimate. Substituting it in the objective function and denoting the resulting sum of squared residuals as S_T(T_1,….,T_m), the estimated break dates $(\hat{T}_1, \ldots\ldots \hat{T}_m)$ are such that

$$(\hat{T}_1, \ldots\ldots \hat{T}_m) = \arg \min_{T_1 \ldots\ldots T_m} S_T(T_1, \ldots\ldots Tm)$$

where the minimization is taken over all partitions (T_1,….,T_m) such as $T_i - T_{i-1} \geq$ [εT]. The term [εT] is interpreted as the minimal number of observations in each segment. Thus the breakpoint estimators are global estimators and are global minimisers of the objective function. Finally, the regression parameter estimates are obtained using the associate least-squares estimates at the estimated m-partition, $\{\hat{T}_j\} i, e. \hat{\delta} = \hat{\delta}(\{T_j\})$

A Test of Structural Stability versus an Unknown Number of Breaks

Bai and Perron (1998) considered tests of no structural change against an unknown number of breaks given some upper bound M for m. The following new class of tests is called double maximum tests and is defined for some fixed weights $\{a_1 \ldots\ldots\ldots\ldots a_m\}$ as

$$D\max F_T(M, q, a_1, \ldots\ldots\ldots\ldots\ldots\ldots a_M) = \max a_m Sup F_T(\lambda_1, \ldots\ldots\ldots \lambda_n : q)$$
$$= \max a_m F_T(\lambda_1, \ldots\ldots\ldots \lambda_{n : q})$$

The weights $\{a_1 \ldots\ldots\ldots a_m\}$ reflect the imposition of some priors on the likelihood of various numbers of structural breaks. Firstly, they set all weights equal to unity, i.e. $a_m=1$ and label this version of the test as *UDmax*F_T*(M,q)*. Then they consider a set of weights that the marginal p-values are equal across values of m. The weights are then defined as $a_1=1$ and $a_m= c(q, \alpha, 1)/c(q, \alpha, m)$ for m>1, where α is the significance level of the test and c(q, α, m) is the asymptotic critical value of the test $\sup F_T(\lambda_1, \ldots\ldots\ldots \lambda_n : q) \in \Lambda_\varepsilon F_T(\lambda_1, \ldots\ldots\ldots \lambda_n : q)$. This version of the test is denoted as *WD max*F_T*(M, q)*.

The second part of step-III is basically on sequential test.

A Sequential Test

The last test developed by Bai and Perron (1998) is a sequential test of *l* versus *l*+1 structural changes:

$$\sup F_T(l+1/l) = \{S_T(\hat{T}_1, \ldots\ldots\ldots \hat{T}_l) - \min\inf S_T(\hat{T}_1, \ldots\ldots, \tau, \hat{T}i_{-1,} \ldots\ldots\ldots\ldots\ldots\ldots \hat{T}_l)$$

where,

$$\Lambda_{i,n} = \{\tau ; \hat{T}_{l-1} + (\hat{T}_l - \hat{T}_{l-1})\eta \le \tau \le \hat{T}_l + (\hat{T}_l - \hat{T}_{l-1})\eta\},$$

$S_T(\hat{T}_1, \ldots\ldots, \hat{T}i_{-1,}\tau, \hat{T}_i \ldots\ldots\ldots\ldots\ldots\ldots \hat{T}_l)$ is the sum of squared residuals resulting from the least squares estimation from each m-partition $(T_1, \ldots\ldots\ldots\ldots\ldots\ldots T_m)$ and $\hat{\sigma}^2$ is a consistent estimator of σ^2 under the null hypothesis.

The asymptotic distributions of these tests are derived in Bai and Perron (1998) and the asymptotic critical values are tabulated in Bai and Perron (1998, 2003b) for ε = 0.05 (M=9), 0.10 (M=8), 0.15(M =5), 0.20(M=3), and 0.25 (M=2).

After performing the first and second part of step-III, the crucial decision is the selection of major breakpoints.

The Selection Procedure

For determining the number of breaks in the underlying series first one have to look at the *UD max* $F_T(M, q)$and *WD max* $F_T(M, q)$ statistics to check whether there exists at least one structural break or not. Then decide the number of breaks based upon an examination of the sup F_T (l+1/l) statistics constructed using the break date estimates obtained from a global minimization of the sum of squared residuals (i.e. one can select m breaks such that the tests sup F_T (l+1/l) are non significant for any l>m). Bai and Perron (2003) conclude that this method leads to the best results and is recommended for empirical applications.

After the determination of growth rate, it is essential to find out the major factors affecting such growth rate. The next section describes the method of finding out such determinants.

3.2.4 The methodology of simultaneous panel method for finding out the major determinants of growth of output

Indian states have its individuality that influences the growth and performance of different crops in several counts. Thus the growth and performance of different crops in different states do not always move in the same path. A second-stage regression analysis of growth of output of different crops can help to identify factors that enhance or hinder it. This, in its turn, becomes helpful for policy formulation for improving growth of output of different crops. In this second-stage regression, states with no unit root are only considered. As we have considered different major producing states under each crop so for analyzing the determinant of growth rate we need to construct a panel model for each of the crop. Further, while considering the determinant for growth it is found that there exist some explanatory variables which in turn depends on the dependent variable, ie. growth of output. For example in the present case one of the explanatory variable taken for growth of output is the growth of HYV uses which in turn depends on the growth of output. Thus in order to explain the growth of output, one need to formulate a simultaneous equation kind of frame work in the panel setup showing two way dependency between the dependent variable and the explanatory variable. So, to get a comprehensive picture about the possible determinants influencing growth of output of different crops a simultaneous panel regression analysis has been used in order to find out major determinants of growth for the period 1970-71 to 2013-14.The parameters are thus estimated by considering a panel model under a seemingly unrelated regression (SUR) framework where each regression was adjusted for contemporaneous correlation (across units) and cross section heteroscedasticity is adjusted. While estimating the present panel model the chapter test whether fixed effect model is a better fitted model over the random effect model using Hausman test. For regression purpose this chapter considers both the dependent variable and explanatory variables in growth terms.

Equation Specifying Growth of Output:

In this chapter growth of HYV uses, Government irrigation or Private irrigation, Rainfall, Government expenditure on agricultural education, research, and extension, Rural literacy, Agricultural Loan, Regional Variability and Distribution of Land Holding are taken as possible determinants of growth of output and adopts a simultaneous relationship between growth of output and growth of HYV uses in this context it may be mentioned that Gupta (2006) has also used a simultaneous relationship between growth of output and HYV uses. However he has not used simultaneous panel approach. In order to explain the variation in growth rate of output following explanatory variables are considered:

- **Growth of HYV Uses (HYV):** The earlier studies reported that in the post-Green Revolution period the introduction of high yielding variety seeds and chemical fertilizers have increased the efficiency of the food crops and non food crops in the Indian agriculture **(Ray and Ghose, 2014).** So, it will be interesting to see whether the use of HYV has any role to play in promoting output growth of major crops. The variable HYV is measured by the percentage of the cultivated area using high yielding varieties of seeds in logarithmic form.
- **Growth of Government irrigation (GI) or Private irrigation (PI):** Another important determinant of the growth of output is the irrigation. In order to test the role of Government irrigation vis-s-vis Private irrigation in promoting growth the variable GI representing share of Government irrigation in total irrigation and the variable private irrigation measuring share of Private irrigation in total irrigation is taken into account because in the post-Green Revolution era, the newly introduced high yielding variety seeds and chemical fertilizers have greatly enhanced the importance of assured

supply of water through deep well and canal irrigation. Both variables are taken in logarithmic form.

- **Growth of Rainfall (RF):** A significant important factor in this reverence is the amount of rainfall. It is well known that the production in Indian agriculture is heavily dependent upon the monsoon rain of the country. So to find out whether rainfall is significant factor in promoting growth the variable RF i.e. the log value of amount of annual rainfall in a state in a given year is taken into account as an explanatory variable.
- **Growth of Government expenditure on agricultural education, research, and extension (E):** Government expenditure on agricultural education, research, and extension has a positive role on the production because they provide more information about the input uncertainty to the farmers. So if the expenditure on agricultural education, research, and extension have increased then farmers are became more aware about the production uncertainty and they can take more preventive measures in the farming and get higher growth. Government expenditure on agricultural education, research and extension **(E)** is the amount of expenditure divided by total area under agricultural operation in log value.
- **Growth of Rural literacy (RL)**: Similarly Rural literacy also has a positive impact on the production of crops. Rural Literacy Rate **(RL)** collected from the Census. Growth of Rural Literacy is the log value of Rural Literacy.
- **Growth of Agricultural Loan (AL):** Another important determinant is the agricultural loan because agricultural loan for the farmers is necessary for purchasing more HYV seeds, Chemical Fertilizer, Tractors, Pumps, Electricity etc. When a farmer uses these kinds of modern technologies the growth of the output must increased significantly. Agricultural loan **(AL)** is measured by the total amount of credit issued by rural banks and agricultural cooperatives per acre of cultivated area in the state in logarithmic form.
- **Growth of Inequality in Distribution of Operational Land Holding (G):** In agriculture, land reforms and lowering of concentration of ownership occupies an important position for output growth. From the data of marginal holdings of land and number of farmers one can construct the Gini co-efficient for the distribution of operational land holding. Several country level studies looked at the likely relationship between land distribution and productivity. For example Besley and

Burgess (2000) argued that in India, land reforms had their maximum effect in states with greatest initial land inequality. Jeon and Kim (2000) found significant productivity gains from land reforms in Korea during 1950s. Banerjee and Iyer (2005) while investigating the historical nature of land distribution in India locate that states initially having higher land inequality had lower productivity even after land reform took place. A study by Vollarth (2007) using cross country data on inequality in operational holding of agricultural land reform form Deininger and Squire (1998), pointed out the land distribution issue and also the matter of international agricultural productivity. While estimating agricultural production function he found the Gini coefficient for land holdings to have a negative significant relationship with productivity. Now all the above mentioned studies have found significant relationship between distribution of land holding and either efficiency or productivity. So, it will be interesting to see how the distribution of operational land holding affects the growth of output. The inequality of distribution of operational land holding is measured by the Gini ratio **(G)** and was constructed from the data on Census of agriculture and for growth purpose log value is considered.

- **Regional Variability**: Apart from these determinants this chapter has also included regional dummy to incorporate the regional variation in the growth process.

So, $D_i = 1$ if states belong to the ith region.

= 0 otherwise.

Using these above explanatory variables and some preliminary estimate one can specify growth of output (GR) equations for different crops:

Ideally while specifying output growth equation one should keep in mind that output growth will depend also on the input growth. In chapter 5 while estimating the total factor productivity growth we have taken into account seeds, fertilizers, manure uses and human labour etc. collected from cost of cultivation data published by Government of India.

However these data are not available for all the 9 crops and all the major producing states as taken into consideration in this chapter. These inputs data are available only for three crops: Rice, Wheat and Jowar for the major producing states. But since we are employing a panel approach for each of all 9 crops including all the major

producing states and for entire time point we have not included input as the determinant for crops other than Rice, Wheat and Jowar and for Rice, Wheat and Jowar we are including both the growth of inputs [included inputs are fertilizers (F), manure uses (M) and human labour (L)[3]] as well as the explanatory variables as discussed above.

Thus for these three crops Rice, Wheat and Jowar we have two sets of regression

I. Excluding the inputs
II. Including the inputs.

Thus we have used two models.

Model A: Simultaneous Panel Model without growth of inputs as explanatory variable.

Model B: Simultaneous Panel Model with growth of inputs as explanatory variable (only for Rice, Wheat and Jower).

Model A: Simultaneous Panel Model without growth of inputs as explanatory variable

Growth of output equation in case of Rice excluding inputs as explanatory variable:

$$GR = f(RF, HYV, AL, RL, GI, E, G, G^2, RL * E, RF * HYV) \qquad \ldots 1A$$

Growth of output equation in case of Wheat excluding inputs as explanatory variable:

$$GR = f(RF, RF^2, HYV, GI, AL, E, RL, G, G^2, DN, DE, DM) \qquad \ldots 1B$$

Growth of output equation in case of Bajra:

$$GR = f(RF, RF^2, HYV, GI, AL, E, RL, G, G^2, RF * GI, RF * HYV) \qquad \ldots 1C$$

Growth of output equation in case of Gram:

[3] Animal labour is not included as the determinant as most of the entries under animal labour are zero or unavailable.

$$GR = f(RF, RF^2, HYV, HYV^2, GI, AL, E, G, G^2) \quad \ldots 1D$$

Growth of output equation in case of Jowar excluding inputs as explanatory variable:

$$GR = f(RF, HYV, HYV^2, GI, AL, E, G, G^2) \quad \ldots 1E$$

Growth of output equation in case of Maize:

$$GR = f(RF, HYV, PI, AL, E, RL, G, G^2) \quad \ldots 1F$$

Growth of output equation in case of Cotton:

$$GR = f(RF, RF^2, HYV, HYV^2, GI, AL, E, G, G^2, GI * AL) \quad \ldots 1G$$

Growth of output equation in case of Groundnut:

$$GR = f(RF, RF^2, HYV, HYV^2, PI, E, G, G^2, E * AL) \quad \ldots 1H$$

Growth of output equation in case of Rapeseed/ Mustard Oil:

$$GR = f(RF, HYV, HYV^2, PI, AL, E, RL, G, G^2,) \quad \ldots 1I$$

Model B: Simultaneous Panel Model with growth of inputs as explanatory variable (only for Rice, Wheat and Jower)

Growth of output equation in case of Rice including inputs as explanatory variable:

$$GR = f(RF, RF^2, HYV, HYV^2, AL, RL, GI, E, G, G^2, F, M, L, L^2) \quad \ldots 1A^{/}$$

Growth of output equation in case of Wheat including inputs as explanatory variable:

$$GR = f(RF, RF^2, HYV, HYV^2, AL, RL, GI, E, G, G^2, F, M, L, L^2) \quad \ldots 1B^{/}$$

Growth of output equation in case of Jowar including inputs as explanatory variable:

$$GR = f(RF, HYV, HYV^2, AL, RL, PI, E, G, G^2, F, M, L, L^2) \quad \ldots 1E^{I}$$

Equation Specifying Growth of HYV Uses:

In this chapter growth of output, Government irrigation or Private irrigation, Government expenditure on agricultural education, research, and extension, Rural literacy, Agricultural Loan and Regional Variability are taken as possible determinants of growth of HYV uses. So, the variation of HYV Uses is explained by considering the following variables:

- **Growth of Output (GR):** It is well known that with the introduction of Green Revolution policy in 1966 specifically the use of HYV seeds had increased the growth of output in case of rice and wheat in the northern states in India. With this sudden hike in the growth of output farmers were used more and more HYV sees to get more and more output. So, it will be interesting to see whether the growth of output has any role to play in promoting growth of HYV uses in case of rice production.
- **Growth of Government irrigation (GI) or Private irrigation (PI):** Another important determinant of HYV uses is Government irrigation vis-s-vis Private irrigation, because in the post-Green Revolution era, in order to use HYV seeds efficiently the importance of assured supply of water through deep well and canal irrigation is needed. So, it will be interesting to see the effect of Government irrigation vis-à-vis Private irrigation on the growth of HYV uses.
- **Growth of Government expenditure on agricultural education, research, and extension (E):** Government expenditure on agricultural education, research, and extension has a positive role on the HYV uses because as Government expenditure on agricultural education, research and extension increases then new variety of HYV seed are invented and thus uses of more and more HYV seed has increases.
- **Growth of Rural literacy (RL)**: Rural literacy also has a positive impact on the HYV uses because as rural literacy goes up farmers become more and more educated and as farmers became more and more educated they can use HYV seed more efficiently and thus the use of HYV seeds increases.
- **Growth of Agricultural Loan (AL):** Another important determinant is the agricultural loan because agricultural loan for the farmers is necessary for purchasing

more HYV seeds, Chemical Fertilizer, Tractors, Pumps, Electricity etc. So, there exists a positive relationship between growth of agricultural loan and HYV uses.

- **Regional Variability:** Apart from the above mentioned determinants this chapter has also included regional dummy to incorporate the regional variation in the growth of HYV Uses.

So, $D_i = 1$ if states belong to the ith region.

= 0 otherwise.

Using these above explanatory variables and some preliminary estimate one can have the following specification of Growth of HYV Uses:

Model A: Simultaneous Panel Model without growth of inputs as explanatory variable

Growth of HYV uses equation in case of Rice excluding inputs as explanatory variable:

$$HYV = f(GR, GR^2, GI, AL, RL, E, E*AL, DN, DS) \qquad \ldots 2A$$

Growth of HYV uses equation in case of Wheat excluding inputs as explanatory variable:

$$HYV = f(GR, GR^2, PI, AL, RL, E, E*AL) \qquad \ldots 2B$$

Growth of HYV uses equation in case of Bajra:

$$HYV = f(GR, GR^2, AL, RL, E, DW, DN) \qquad \ldots 2C$$

Growth of HYV uses equation in case of Gram:

$$HYV = f(GR, GR^2, GI, AL, RL, E, DM, DN, DW) \qquad \ldots 2D$$

Growth of HYV uses equation in case of Jowar excluding inputs as explanatory variable:

$$HYV = f(GR, GR^2, GI, AL, RL, DW, DS) \qquad \ldots 2E$$

Growth of HYV uses equation in case of Maize:

$$HYV = f(GR, GR^2, GI, RL, E, DE, DW, DM, DS) \quad \ldots 2F$$

Growth of HYV uses equation in case of Cotton:

$$HYV = f(GR, GR^2, GI, AL, RL, E, DW, DN, DS) \quad \ldots 2G$$

Growth of HYV uses equation in case of Groundnut:

$$HYV = f(GR, GR^2, GI, AL, E, RL) \quad \ldots 2H$$

Growth of HYV uses equation in case of Rapeseed/ Mustard Oil:

$$HYV = f(GR, GR^2, GI, AL, RL, DN, DE, DW) \quad \ldots 2I$$

Model B: Simultaneous Panel Model with growth of inputs as explanatory variable (only for Rice, Wheat and Jower)

Growth of HYV uses equation in case of Rice including inputs as explanatory variable:

$$HYV = f(GR, GR^2, GI, AL, RL, E, F, DS, DN) \quad \ldots 2A^{/}$$

Growth of HYV uses equation in case of Wheat including inputs as explanatory variable:

$$HYV = f(GR, GR^2, PI, AL, RL, E, F, DE, DN) \quad \ldots 2B^{/}$$

Growth of HYV uses equation in case of Jowar including inputs as explanatory variable:

$$HYV = f(GR, PI, AL, RL, E, F, DW) \quad \ldots 2E^{/}$$

Now these set of two equations for each of the crop satisfy both order and rank condition of simultaneous equation system. In fact the model is over identified. We have solved the identification problem by imposing exclusion restriction. It is found that each of the two equation contain separate variables and hence the mongrel equation can easily differentiable from the growth equation and growth of HYV equation and hence both the equation are identified.

Method for Estimation:

Problem of Simultaneity

Now from equations (1A…1I) and (2A…2I) used for finding out the factors determining growth rate of output one can conclude that there exists a simultaneous relationship between growth of output and Growth of HYV uses. To address this issue, a two stage method of estimation is adopted for the panel model.

Two stage estimation method:

Stage 1: Replacing the Growth of HYV uses from equation (2A..2I) into corresponding equation (1A…1I) one can express Growth of output as a function of other variables except growth of HYV uses. This is the reduced form equation of growth of output. Similarly, replacing growth of output from equation (1A…1I) to corresponding equation (2A…2I) one can get Growth of HYV uses as a function of other variables except growth of output. This is the reduced form equation of Growth of HYV uses.

Now, from the reduced form equations of growth of output and HYV uses one can get estimates of the parameters of both these two equations.

Stage 2: Replacing this estimated value of growth of output as obtained from stage 1 in corresponding equations (2A…2I) one can get the final estimate of the growth of HYV uses using the panel model under SUR framework. Similarly, one can replace the estimated value of growth of HYV uses as obtained from stage 1 in corresponding equation (1A..1I) to get the final estimate of the growth of output also using the panel setup. The proposed setup of the panel model uses seemingly unrelated regression (SUR) framework as described below.

Seemingly unrelated regression model (SUR)

SUR is appropriate when all the right hand side regressors X are assumed to be exogenous, and the errors are heteroscedastic and contemporaneously correlated so that the error variance matrix is given by$V = \sum \otimes I_T$. Zellner's SUR estimator of β takes the following form:

$$b_{SUR} = (X^{/} (\hat{\sum} \otimes I_T)^{-1} X)^{-1} X^{/} (\hat{\sum} \otimes I_T)^{-1} y$$

Where $\hat{\sum}$ is a consistent estimate of $\sum$ with typical element s_{ij}, for all *i* and *j*. If autoregressive terms are included in the equation, then the following equation is estimated:

$$y_{jt} = X_{jt}\beta_j + \left[\sum_{r=1}^{p_j} p_{jr} \left(y_{j(t-r)} - X_{j(t-r)} \right) \right] + \epsilon_{jt}$$

where ε_j is assumed to be serially independent, but possibly correlated contemporaneously across equations.

Now, one can estimate GLS specifications that account for various patterns of correlation between the residuals. In this chapter contemporaneous covariances is taken into the consideration.

Cross Section SUR or Contemporaneous Covariances:

This class of covariance structures allows for conditional correlation between contemporaneous residuals for cross section "i" and "j", but restricts residuals in different periods to be uncorrelated, specifically that:

$E(\in_{it} \in_{jt} / x_t^*) = \sigma_{ij}$

$E(\in_{is} \in_{jt} / x_t^*) = 0$

For all "i", "j" , "s" and t with s≠t. The error terms may be thought of as cross-sectionally correlated. Alternatively, this error structure is sometimes referred to as clustered by period since observations for a given period are correlated.

Using the period specific residual vectors one may rewrite this assumption as :

$E(\in_t \in_t^{/} / x_t^*) = \Omega_M$

For all t, where

$$\Omega_M = \begin{bmatrix} \sigma_{11} & \cdots & \sigma_{1M} \\ \vdots & \ddots & \vdots \\ \sigma_{M1} & \cdots & \sigma_{MM} \end{bmatrix}$$

This is a cross section specification because it involves covariances across cross section as in a seemingly unrelated regression type framework. Cross section SUR generalized least squares on this specification is simply the feasible GLS estimator for systems where the residuals are both cross sectionally heteroscedastic and contemporaneously correlated. EViews employs residual from first stage estimates to form an estimate of Ω_M. In the second stage, they perform feasible GLS.

i. White Cross-Section or Cross Section Heteroscedasticity:

The White Cross-Section method assumes that the errors are contemporaneously (Cross-Sectianally) correlated (Period Clustered). The method treats the pooled regressions as a multivariate regression (with an equation for each cross section) and computes robust standard errors for the system of equations. The coefficient covariance estimator is as follows:

$$\left(\frac{N^*}{N^* - K^*}\right)\left(\sum_t X_t^/ X_t\right)^{-1}\left(\sum_t X_t^/ \widehat{\epsilon_t}\, \widehat{\epsilon_t^/}\ X_t\right)\left(\sum_t X_t^/ X_t\right)^{-1}$$

Where the leading term is a degrees of freedom adjustment depending on the total number of observations in the stacked data, N^* is the total number of stacked observations and K^* is the total number of estimated parameters.

3.2.5 The Data sources

All the data has been collected from the different issues of the Statistical abstract, Agriculture at a Glance, Agriculture in Brief, Handbook of Statistics on Indian Economy, *www.indianstat.com* (an online commercial data service) and Cost of Cultivation data published by the Government of India.

3.3 Results of estimation

It has already been discussed that a complete growth analysis requires test for unit root and this will be followed by trend analysis. But the traditional unit root analysis is not suitable in the presence of structural break. So to determine whether the series are convergent series or not one has to check unit root in the presence of one time structural break due to Sen (2003). Now it may possible that there exists more than one structural break. So, one has to check the presence of multiple structural breaks due to Bai and Perron (1998, 2003). After this it is interesting to analyze which are the major determinants behind the growth. So, the following subsection 3.3.1 presents results of unit root analysis. The results of the trend analysis are presented in subsection 3.3.2. The subsection 3.3.3 presents the results of convergence analysis for different series and their break points. The results of the performance of different crops on the basis of their growth pattern are presented in subsection 3.3.4. Subsection 3.3.5 presents the results of multiple structural break analysis. Interesting results from comparison between multiple structural breaks and single structural break are presented in subsection 3.3.6. The results of simultaneous panel for determining the major factor behind the growth not by taking input growth as the explanatory variable for different crops are presented in subsection 3.3.7. Lastly, subsection 3.3.8 presents the results of determinant analysis by taking input growth as the explanatory variables for rice, wheat and jowar.

As mentioned before the estimation of growth rate will required first of all test for unit root and this will followed by trend analysis. The results of unit root tests and the results of trend analysis for different selected crops are presented in Table 3.1 to 3.18. We have then performed unit root analysis in presence of one time structural break due to Amit Sen (2003). Based on the results of Amit Sen (2003) we have classified the good, bad and moderate performing crops. Table 3.19 describes the criterion of Good, Moderate and Bad performing crops. Table 3.20 describes the results of the nature of the series of different food crops based on Sen (2003) approach. Tables 3.21 to Table 3.26 represent the results of Amit Sen approach for different food crops and states. The results of nature of the series of different non food crops biased on Sen (2003) approach are presented in Table 3.27. Tables 3.28 to Table 3.30 represent the results of Amit Sen approach for different non food crops and states. The results of State-wise performances of selected nine crops are presented in Table 3.32 to 3.40. After that we have carried out multiple structural break analysis due to Bai and Parron (1998, 2003). The results of Bai-Perron method for all selected crops are obtainable in Table 3.41 to

3.49. This is followed by determinant analysis without taking input growth as the explanatory variable for all selected nine crops. All the results of simultaneous panel for determining the major factors behind the growth not by taking input growth as the explanatory variable for different crops are presented in Table 3.50 to 3.104. The results of determinant analysis by taking input growth as the explanatory variable for rice, wheat and jowar are presented in Table 3.105 to 3.122.

3.3.1 Results of Unit Root Test

The results of ADF test, PP test and KPSS test in case of Rice, Wheat, Bajra, Gram, Jowar, Maize, Cotton, Groundnut and Rapeseed/Mustard Oil are presented in Table-3.1, 3.3, 3.5, 3.7, 3.9, 3.11, 3.13, 3.15 and 3.17 respectively.

Among the food crops the results of unit root test suggests that in case of rice among all the eleven major rice producing states the underlying process is Difference Stationary (DS) in case of Madhya Pradesh only for all the three cases. In case of wheat ADF, PP and KPSS statistics shows that all the six major wheat producing states have stationary series in case of growth of output. The results of unit root test in case of Bajra and Gram suggest that the underlying series is Trend Stationary (TS) for all the major Bajra and gram producing states. In case of Jowar and Maize ADF, PP and KPSS statistics suggest that all sample states shows stationary series in case of growth of output.

In case of non food crops the results of ADF, PP and KPSS test suggest that the underlying series is stationary for all selected states in case of Groundnut and Rapseed/Mustard Oil.

So, from the results of unit root test it can be concluded that for all the sample states in case of all the crops the series are found to be stationary excepting rice for MP. Now, by applying the multiple structural break analysis one can check whether there exists any significant trend in the series or not in case of all the sample states for all the crops excepting MP in case of rice production.

3.3.2 Results of Trend Analysis

The results of trend analysis in case of Rice, Wheat, Bajra, Gram, Jowar, Maize, Cotton, Groundnut and Rapeseed/Mustard Oil are presented in Table-3.2,3.4,3.6,3.8,3.10,3.12,3.14,3.16 and 3.18 respectively.

In case of rice and wheat the ADF, PP and KPSS test suggest that there exist a significant positive trend for all the states which has stationary process. So, one can apply multiple structural break analysis for all states in case of rice and wheat production. In case of Bajra the underlying trend is positive and statistically significant in case of HA, MA, RA and UP. But in case of GU and KA the underlying trend is insignificant in case of ADF, PP and KPSS test. So, in case of Bajra one can't apply the multiple structural break analysis for GU and KA. In case of Gram the underlying trend is negative and statistically significant in case of BI, RA and UP. In case of HA, MP and MA the underlying trend is positive and statistically significant. The deterministic trend is insignificant in case of MA and RA for Jowar. But this deterministic trend is negative and statistically significant in case of AP, GU, KA, TN and UP. In case of Maize the underlying trend is positive and statistically significant for all the states excepting PU. In case of PU the underlying trend is negative and significant. Thus, from the results of the trend analysis it can be concluded that multiple structural break analysis is applicable for all the sample states in case of all food crops excepting GU and KA for of Bajra and MA and RA in case of Jowar.

Now, among the non food crops the underlying trend is insignificant in case of MP for cotton production. For rest of the states in case of cotton the underlying trend is positive and statistically significant. In case of Groundnut the underlying trend is significant and positive for GU only. For rest of the states the underlying trend is insignificant. In case of Rapeseed/Mustard Oil the underlying trend is negative and significant only in case of UP and for rest of the states the underlying trend is positive and statistically significant. So, in case of non food crops multiple structural break analysis is not applicable in MP for cotton and AP, KA, MP and TN for Groundnut.

3.3.3 Results of test on convergence of the different series and their break points

The results of the nature of the series i.e. whether the growth process converges to a path having trend preserving properties, for each of the crops like Rice, Wheat, Bajra, Gram, Jowar and Maize are presented in Table 3.20 and in Table 3.27 the results for Cotton, Groundnut and Rapeseed/Mustard Oil are presented. It is found that for all selected crops and also for all selected states the underlying series is Trend stationary. Thus, it can be concluded that for all selected crops and sates the underlying series converges to a trend stationary process.

By analyzing the results of the break points it can be concluded that in case of rice, cotton and groundnut most break points occurs in the first half of the last decade. In case of wheat, jowar, groundnut and Rapeseed/Mustard Oil most break points occurs in the last half of the 70's decade. Also the effect of the introduction of liberalization policy is prominent in case of bajra and jowar. In case of maize most of the break points occur in the decade of 80's.

3.3.4 Performance of different crops on the basis of their growth pattern

The results of overall growth rate and the change in the growth rate as well as the level of the series after the break point for all crops and all states are presented in Table 3.21 to 3.26 and Table 3.28 to 3.30.

Depending on the growth performance of all crops following TS process, states are classified into different groups: (i) Group A (Good performer), (ii) Group B (Moderate performer) and (iii) Group C (Bad performer). The criterions for belonging to different groups A, B, or C are defined in Table 3.19.

It is found that there is wide variation among the growth of major selected crops across states which can be summed up as follows:

First of all, the estimated results suggest that none of the states are good performer for all crops.

Secondly, the performance is **moderate** for the following states (i) AP, HA, BI, KA, MP, OR, PU, TN, UP and WB in case of rice; (ii) In case of wheat BI, HA, PU and UP; (iii) For bajra, GU, HA, KA, MA, RA and UP; (iv) AP, GU, KA, MA, RA and UP for jowar; (v) In case of maize AP, BI, GU, HP, KA, MP, RA and UP; (vi) BI, HA, MA, MP, PU, RA and UP in case of gram; (vii) AP, GU, HA, KA, PU and RA in case of cotton; (viii) for groundnut AP, GU, MP and TN; (ix) in case of rapeseed/mustard oil HA, MP, RA, UP and WB.

Finally, the performance is **bad,** for the following states (i) AS in case of rice; (ii) MP and RA in case of wheat; (iii) TN in case of jowar; (iv) PU for maize; (v) in case of cotton MP and MA; (vi) KA for groundnut; (vii) AS and GU in case of rapeseed/mustard oil.

Table 3.31 represent the overall performance of the crops and also the corresponding states belonging to the moderate and bad performing groups. Tables 3.32 to 3.40 represent the detailed performance of the states. We have also calculated the share of production for those states whose performance is bad to check whether the performance of the state may affect the overall performance of the crops or not. For example, the results suggest that in case of rice average share of AS, which is found to be a bad performing sate, is 8.59% only. Hence the share of the bad performing state, AS, in total production is not sufficiently high which rules out the possibility of AS to make rice a moderate performer. In case of wheat the joint average share of MP and RA is around 19%. The share of TN in case of jowar is 5.6% and PU in case of maize is 7%. In case of cotton the joint average share of MA and MP is 12.07%. In case of groundnut the average share of KA is 14% and in case of rapeseed/mustard oil the average share of AS and GU is 4.9%. So by analyzing the share it can be concluded that the share of production for the states whose performance are bad is not large enough to make these crops a moderate performer.

3.3.5 Results of Multiple Structural Break Analysis

The results of multiple structural break analysis in case of Rice, Wheat, Bajra, Gram, Jowar, Maize, Cotton, Groundnut and Rapeseed/Mustard Oil are presented in Table-3.41, 3.42, 3.43, 3.44, 3.45, 3.46, 3.47, 3.48 and 3.49 respectively.

From the results of multiple structural break analysis of **rice** it can be concluded that both UD Max and WD Max statistic are significant at 5% level for all the states. This implies that for all the states there exists atleast one break in the deterministic trend. Now after getting the results that there exist atleast one break in the deterministic trend one have apply the sequential test to find out the actual numbers of breaks and the break dates.

From the results of the sequential test it can be concluded that in case of AP there exists three breaks in the series which occurs at 1984, 1991 and 2002. In case of AS the estimated break dates are 1990, 1998 and 2004. In case of BI and PU there exist two breaks in the deterministic trend which are 1994, 2004 and 1977, 1983 respectively. In case of TN, UP and WB there exist three breaks in the series and the estimated break dates are 1977, 1984 and 2002 in case of TN, 1978, 1988 and 2002 in case of UP and in case of WB the estimated break dates are 1982, 1987 and 2001. In case of HA and OR there exist four breaks in the deterministic trend of the series which are 1976, 1987, 1993 and 2005 in case of HA and 1977, 1983, 1996 and 2003 in case of OR. In case of KA there exists only one break in the series which occurs at 1995.

In case of **wheat** both UD Max and WD Max statistics suggest that there exist atleast one break in the series for all the states. Now, the sequential statistics suggest that there exist a strong interstate variation in terms of multiple structural breaks in case of wheat production. For example there exist four breaks in the series for HA, PU and UP whereas two numbers of breaks in case of BI and MP. There exist three numbers of breaks in case of RA.

For **Bajra** both UD Max and WD Max statistics suggest that there exist atleast one break in the series for all the states. According to sequential test, there exist two numbers of breaks in case of HA, MA, RA and UP. But the dates of occurrence of the breaks are different from state to state.

In case of **Gram** there exist two breaks in the series for all the states except UP. In case of UP there exist three breaks in the series.

For **Jowar** the results of multiple structural break analysis suggest that both UD max and WD max statistics fail to reject the null hypothesis of no break in case of KA. In case of TN and UP there exist two breaks in the series. For AP there exist three breaks and for GU there exists one break in the series.

In case of **Maize** there exist four breaks in the series for AP and PU. In case of GU, HP and KA there exist three breaks in the series whereas there exist two breaks in the series in case of BI, MP and RA. In case of UP there exists one break in the series.

Now, among the non food crops in case of **cotton** production there exist three breaks for AP. HA and MA. In case of GU, KA, PU and RA there exists one break in the series for cotton.

In case of **Groundnut** the multiple structural break analysis is applicable only for GU and there exists one break in the series. For rest of the states there exists no significant deterministic trend and hence multiple structural break analysis is not possible.

In case of **Rapeseed/Mustard Oil** there exist three breaks in the series for GU, MP, RA, UP and WB. For HA there exist two breaks in the series whereas in case of AS there exists one break in the series.

Now from the results of the multiple breaks analysis **regional variation is very much prominent among the states and also among the crops.** For example in case rice for PU and HA breaks occurs at mid 70's and mid 80's. One of the causes of occurrence of the breaks at mid 70' may be the effect of green revolution. On the other hand in case of WB first break occurs at 1982. In case of wheat for most of the states first break occurs at late 70's. In case of Bajra, break points occur either on early 90's or after 2000. For rest of the crops, the occurrence of break points differ from state to state and also from crop to crop.

Another important result is that in case of most of the sample states for all crops one break occurs at 90's. These may be due to the introduction of liberalization policies by the central government. In July 2000, the Government of India had introduced a policy in agricultural sector which is known as the "New agricultural Policy, 2000". The introduction of the New Agricultural Policy, 2000 may affect the crop production because most of the states have one break in the first decade of this century in case of all the crops. Thus although there exists a strong regional variation among the states in terms of multiple breaks but any change of policy by the central government may affect the crop production as a whole.

Now, from this multiple structural break analysis it can be concluded that there exist breaks in the series. But it cannot be concluded that whether the series is convergent towards a trend or not. For this analysis one has to consider the endogenous structural break analysis with one time shock in the series[4] following Sen (2003).

3.3.6 Results of Multiple Structural Breaks Vs. Single Structural Break

Now, combining the results of multiple structural break and the results of endogenous structural break it can be concluded that in case of **rice** the major breaks occur for AP, AS, BI, HA, KA, MP, OR, PU, TN, UP and WB at or between the years 2002-04, 2004-06, 2004-06, 1976, 1991-94, 2000, 2003-04, 1977-79, 2002-04, 1987-88 and 1982-83 respectively. For **wheat** major breaks are at or between 1985-87, 1975-78, 1993-95, 1975-77, 1996-98 and 1975-76 in case of BI, HA, MP, PU, RA and UP respectively. In case of **bajra**, for the states like GU, HA, KA, MA, RA and UP major breaks are 1991, 1991-94, 1976, 186-87, 1990-91 and 1991-92 respectively. The occurrence of major break year are 1986-88, 1983-86, 1976,

[4] One time shock has been considered because results of multiple structural analyses suggest that almost for all cases there exist at least one break in the series. One can apply Sen (2003) method for those cases for which trends are insignificant because this trend may get significant after the break. Furthermore insignificant trend occur as a results of ADF, PP or KPSS test. But Perron (1989) suggests that in presence of structural break the traditional unit root method may not give correct results.

1976, 2006, 1991-92 and 1995-97 for the states AP, GU, KA, MA, RA, TN and UP respectively in case of **jowar**. In case of **maize,** for the sates AP, BI, GU, HP, KA, MP, PU, RA and UP the major break comes at or between the years 1980-84, 1991-94, 1987-89, 1983-86, 1989, 1981-84, 1988-90, 1986-89 and 1984-86 respectively. For **gram** major selected states are BI, HA, MP, MA, RA and UP and major breaks occur at 2001-02, 1999-2000, 1979-81, 1986-89, 1999-2000 and 1986-87 respectively.

Now, in case of **cotton** for the sates AP, GU, HA, KA, MA, MP, PU and RA the major breaks are 1976-79, 1999-2003, 2004, 2005, 1993-95, 2004, 2000-04 and 1988-1990 respectively. For **groundnut** the major breaks are 1978, 2001-03, 1991, 1977 and 2006 for the sates AP, GU, KA, MP and TN respectively. In case of **rapeseed/mustard oil** the major breaks occur at or between 1980-81, 1982-85, 1980-81, 1979-80, 1978-81, 1989-90 and 1978 for the sates AS, GU, HA, MP, RA, UP and WB respectively.

So, by analyzing these results it can be concluded that there exist a strong intercrop as well as interstate variation and since break point for some of the cases occurs either in the period after 1991 (the time point where the first liberalization process started for the Indian economy) or after 2000 (the time point where the New Agricultural Policy was introduced). Thus, the introduction of these policy changes by the central government may affect the growth of the crops as well.

3.3.7 Results of Determinants of Growth of Output from Model A: Not by Taking Input Growth as One of The Explanatory Variable

The results of the determinant analysis by considering only technological and policy variables as the explanatory variables are presented in Table 3.50 to 3.104.

While estimating the panel model, to test for appropriateness of the assumption of fixed effect vis a vis the random effect model, Hausman's specification test is performed for each of the regression which strongly rejects the assumption of random effect model and supports the assumption of fixed effect model.

For finding out the determinants of Growth of Output using simultaneous panel model, a panel regression has to be considered. For constructing the panel data major producing states has to be considered under each crops over the period 1970-71 to 2012-13.

It may be mentioned that all the estimated equations are found to be nonlinear with some variables. Thus the sign of marginal effects will help to understand the positive or negative relationship for those variables which are nonlinearly related with the dependent variable in each equation. Needless to mention, those variables having linear relationship with the dependent variables in the different equations, sign of the corresponding coefficients will matter for finding out whether the concerned variable has a positive or negative relationship with the dependent variable.

The estimated models also reports Adjusted R^2 which represents the overall fit of the model, which is based on the difference between residual sum of squares from the estimated model and the sum of square from a single constant only specification, not from a fixed effect only specification. High value of Adjusted R^2 shows that the fitted models are reasonably good.

The statistical significance of those variables which are non linear in nature has been checked by Wald test.

Since this chapter uses simultaneous equation kind of framework having two endogenous variables: (i) for growth of output and (ii) the growth of HYV, for each of the crop two equations is estimated; the growth of output equation and the growth of HYV equation.

In case of **rice** growth of output is positively and significantly related with growth of rainfall, HYV uses, government irrigation, government expenditure on agricultural research and extension and rural literacy. Among them there exist nonlinear relation between growth of rice and growth of rainfall and HYV uses. The sole effect of growth of rainfall and HYV uses is positive but the interaction effect of growth of rainfall and HYV uses on growth of rice is negative. The marginal effect of growth of rainfall and HYV uses is found to be positive which implies that positive sole effects dominates the negative interaction effect. Similarly the sole effect of government expenditure on agricultural research and extension and rural literacy is positive and the interaction effect of growth of government expenditure on agricultural research and extension and rural literacy is also positive. Thus growth of government expenditure on agricultural research and extension and rural literacy has positive effect on growth of rice production. On the other hand growth of rice is negatively and significantly related with operational land holding. This non-linear relationship implies too much small holding of land may hamper the growth of rice.

Again as there exist a simultaneous kind of relationship between growth of output and growth of HYV uses. The growth of HYV uses may be significantly and positively affected by the growth of rice, government irrigation, agricultural loan, rural literacy and government expenditure on agricultural research and extension. The growth of rice and the growth of HYV uses have non linear relationship. The first polynomial of the growth of rice is positive and statistically significant while the second polynomial is negative and statistically significant implying that there exists a threshold limit beyond which growth of rice production may decrease the growth of HYV uses. The regional dummies of northern and southern region taking middle as base are positive and significant implying that growth of HYV uses is more in the northern and southern region than in the middle region.

In case of **wheat** the determinants of growth of output is almost same as in case of rice. Here growth of rainfall has only nonlinear relation with the growth of wheat production. The first polynomial of growth of rainfall is positive and second polynomial of growth of rainfall is negative implying that there exists a threshold limit beyond which growth of rainfall may hamper the growth of wheat production. Thus too much rainfall is bad for growth of wheat production. The growth of HYV uses, government irrigation, government expenditure on agricultural research and extension, agricultural loan and rural literacy has a significant positive effect on growth of output in case of wheat. Not only is this the dummy variable, taking western region as base, as in case of northern region, eastern region and middle region are positive and statistically significant. Here western region is taken as bench mark. This implies that northern region, eastern region and middle region has better growth rate than western region.

On the other hand, determinants of HYV uses are almost same as in case of rice excepting the growth of private irrigation. The growth of private irrigation has positive and significant effect on growth of HYV uses.

In case of **bajra** the determinants of growth of output is same as in case of rice excepting that here growth of rainfall has another interaction term with government irrigation which is negative but statistically insignificant. In case of the determinants of HYV uses the result is almost same excepting the regional dummies. The effect of northern region dummy is positive and significant whereas the effect of western region dummy is negative and statistically significant. Here southern region is taken as the base region because the share of southern region is minimum.

In case of **gram** the growth of output is positively and significantly affected by the growth of rainfall, HYV uses, private irrigation, government expenditure on agricultural research and extension and agricultural loan. Among these variables there exists non-linear relationship between growth of gram and growth of rainfall and HYV uses. The first polynomials of these two variables are positive but the second polynomials are negative. The interpretation of this result is same as mentioned earlier. The relationship between the growth of gram and operational land holding is same as above.

Similarly, growth of HYV uses may be significantly and positively affected by the growth of gram, government irrigation, government expenditure on agricultural research and extension, agricultural loan and rural literacy. The coefficient of regional dummies suggests that northern region western region and middle region uses more HYV than eastern region.

In case of **jowar** the major significant variables behind the growth of output is almost same as in case of gram excepting growth of rainfall. Here growth of rainfall has linearly related with growth of jowar. Again growth of rural literacy is not a significant variable in case of jowar.

On the other hand there exists a non-linear relationship between growth of HYV uses and growth of jowar. In case of regional dummies the dummy for western region and southern region has negative and significant effect implying that growth of HYV uses is more in case of northern region than the other two regions.

In case of **maize,** the major influencing determinants behind the growth of maize are rainfall, HYV uses, private irrigation, government expenditure on agricultural research and extension, agricultural loan, rural literacy and operational land holding. Among these variables all the variable has significant positive effect on growth of maize excepting operational land holding. There exists a significant negative relation between the growth of maize and operational land holding.

From the determinants of growth of HYV equation, it can be concluded that all the major determinants of growth of HYV uses are growth of maize, government irrigation, government expenditure on agricultural research and extension and rural literacy. From the sign of regional dummy it can be seen that eastern, western, middle and southern region uses less HYV than the northern region.

In case of **cotton** the results are similar as in case of gram. Only the government irrigation and agricultural loan has a interaction effect which is significant and positive for the growth of cotton.

For the determinants of growth of HYV uses the results is same as in case of gram except the result of regional dummies. In case of cotton western region, northern region and southern region has positive and significant effect on growth of HYV uses.

In case of **groundnut** there exists non-linear relation between the growth of groundnut and rainfall, HYV uses and operational land holding. The interpretations of these results are same as earlier. The other variable which are significant and positive are private irrigation and government expenditure on agricultural research and extension.

On the other hand the major determinants of the HYV uses are growth of groundnut, agricultural loan, government irrigation, rural literacy and government expenditure on agricultural research and extension.

In case of **rapeseed/mustard oil** the major determinants of the growth of rapeseed and mustard oil are rainfall, HYV uses, private irrigation, government expenditure on agricultural research and extension, agricultural loan, rural literacy and operational land holding.

On the other hand, major determinants of the growth of HYV uses are growth of output, agricultural loan, rural literacy and government irrigation. Apart from this in case of rapeseed and mustard oil eastern, northern and western region uses moe HYV than the middle region.

Thus, although there exists a strong inter crop variation in terms of the determinant of growth of output some common results also exist. For example too much rainfall is not good for the growth of output. Although there exists non linear relationship between growth of output and HYV uses and the marginal effect of growth of HYV uses is positive implying that if HYV uses increase then growth of output also increase. On the other hand too small holding of land also effect the growth of output in the reverse way. Again agricultural loan is significant and positive for almost all crops implying that availability of more money may push the farmers for using more and more HYV seeds. Government or Private irrigation, government expenditure on agricultural research and extension and rural literacy has significant positive effect on the growth of output for almost all crops. One significant result is that, the marginal effect of growth of HYV uses on growth of output is highest among the all explanatory variable for all crops.

3.3.8 Results of Determinants of Growth of Output from Model B: By Taking Input Growth as One of The Explanatory Variable

All the results of determents of growth of output for rice, wheat and jowar by taking input growth as explanatory variables are presented in Tables 3.105 to 3.122.

Now from the Table 3.105 and 3.107 it can be concluded that the growth of output in case of **rice** is positively and significantly related with growth of rainfall, HYV uses, government irrigation, government expenditure on agricultural research and extension, agricultural loan and rural literacy, fertilizers uses, manure uses and use of human labour. Among these explanatory variables, there exist nonlinear relation between growth of rice and growth of rainfall, HYV uses and human labour. In case of all these three variables the first polynomial is positive and statistically significant and the second polynomial is negative and statistically significant. Thus the results suggest that too much rainfall and HYV uses are bad for output growth. The result for human labour suggests that if growth of human labour increases then in the first stage growth of output increases but there exists a threshold limit after that growth of human labour uses may affect the growth of output in the reverse way. Thus there exists a optimum employment after which increase in employment growth may led to decrease in growth of output. The output growth of rice is positively and significantly related with the growth of government irrigation, government expenditure on agricultural research and extension, agricultural loan, rural literacy, fertilizers uses and manure uses. These relationships are linear in nature. On the other hand growth of rice is negatively and significantly related with operational land holding. This non-linear relationship implies too much small holding of land may hamper the growth of rice.

From the results of Table 3.106 and 3.109 it can be concluded that there exist a simultaneous relationship between growth of output and growth of HYV uses. The growth of

HYV uses may be significantly and positively affected by the growth of rice, government irrigation, agricultural loan, rural literacy and government expenditure on agricultural research and extension and fertilizer uses. The growth of rice and the growth of HYV uses have non linear relationship. The first polynomial of the growth of rice is positive and statistically significant and the second polynomial is negative and statistically significant implying that there exists a threshold limit beyond which growth of rice production may decrease the growth of HYV uses. On the other hand the growth of government irrigation, agricultural loan, rural literacy and government expenditure on agricultural research and extension and fertilizer uses have a linear, significant and positive impact on the growth of HYV uses. The regional dummy of northern region is positive and significant indicating that growth of HYV uses is more in the northern region than in the middle region.

In case of **wheat** the results of determinants of growth of output are presented in Tables 3.111, 3.113 and 3.114. Now, from these results it can be concluded that the results of determinants of growth of wheat is same as in case of rice except manure uses. In case of growth of manure uses although the coefficient is positive but it is insignificant.

On the other hand the results of determinants of HYV uses are presented in Tables 3.112, 3.115 and 3.116. In case of wheat the growth of HYV uses is positively and significantly affected by the growth of growth of wheat, private irrigation, agricultural loan, rural literacy, government expenditure on agricultural research and extension and fertilizer uses. Among these explanatory variables the growth of wheat is non-linearly related with the growth of HYV uses. This relationship is same as in case of rice. The dummies for northern and eastern region are statistically significant. Among these dummies the coefficient of northern region dummy is positive and the coefficient of eastern region is negative suggesting that northern region states are using more HYV than in case of western region and the states belonging to eastern region use less HYV than western region.

The results of determinants of growth of jowar have been presented in Table 3.117, 3.119 and 3.120. From the results it can be concluded that the growth of jowar is positively and significantly related with rainfall, HYV uses, private irrigation, government expenditure on agricultural research and extension, agricultural loan and rural literacy and use of human labour. Now among the input uses only significant input which has a positive effect on growth of jowar is human labour but this relationship is non-linear in nature. The first polynomial is positive and statistically significant and the second polynomial is negative and statistically significant implying that after a limit growth of employment may hamper the growth of jowar. On the other hand the growth of fertilizer uses and growth of manure is insignificant. The growth of HYV uses is also non-linearly related with the growth of jowar. The results suggest that too much dependency on HYV uses is bad for growth of jowar. On the other hand growth of jowar is positively and significantly related with rainfall, private irrigation, government expenditure on agricultural research and extension, agricultural loan and rural literacy. These relationships are linear in nature. Growth of jowar is negatively and significantly related with distribution of operational land holding. This non-linear relationship points out that too much small holding of land may hamper the growth of jowar.

The results of determinants of HYV uses for jowar are presented in Tables 3.118, 3.121 and 3.122. The results suggests that in contrast with rice and wheat, for jowar the growth of HYV uses is linearly, positively and significantly related with growth of growth of jowar, private irrigation, agricultural loan, rural literacy, government expenditure on agricultural research and extension and fertilizer uses. The coefficient of western dummy is negative and statistically significant which implies that western region uses less HYV than the northern region in case of jowar.

Thus in short it can be concluded that too much dependency on rainfall and HYV uses are bad for the growth of output. Apart from this too small holding of land is also bad for growth of output. For government irrigation, government expenditure on agricultural research and extension, agricultural loan and rural literacy there is a significant and positive relationship between these variables and the growth of output. There is a non linear inverted U shape relationship found between growth of output and growth of labour. But the marginal effect of growth of labour is positive implying that growth of labour has positive effect on the growth of output. This is common for all the three crops. The growth of fertilizer uses is positively and significantly affecting the growth of output only in case of rice and wheat. On the other hand growth of manure uses is a significant explanatory variable for growth of output only in case of rice. Lastly growth of fertilizer uses is positively and significantly related with the growth of HYV uses for all the three crops.

3.4. Conclusion

The present chapter analyses the growth performance of Indian agricultural sector for nine selected crops and for each crops major producing states of those crops are selected.

Total sample period of this study is from 1970-71 to 2013-14. In this chapter growth performance of the selected states and crops are analysed by testing whether the growth of the selected crops and states converges to a deterministic trend or not by traditional unit root test and also by Sen(2003) method. After testing the unit root property of the series, the next objective is to identify those crops and states whose performance is good, moderate and bad. Our next objective of this chapter is to check whether there exists any break or breaks in the series by applying the Bai-Perron method of multiple structural breaks. After this, the chapter also recognized the major factors influencing growth of output. The models are estimated, considering the problem of simultaneity, which may occur between growth of output and growth of HYV uses, using simultaneous panel estimation technique under a Seemingly Unrelated Regression (SUR) framework, adjusted for contemporaneous correlation across units and cross-section heteroscedasticity is taken care by White Cross-Section.

Now from the results of the traditional unit root analysis it can be concluded that for all selected crops and also for all selected states the underlying series is Trend stationary except MP for Rice. Inference can be drawn from the results of the Sen(2003) that growth of output series for all the sates and crops are Trend stationary. Thus, one can be conclude that for all selected crops and states the underlying series converges to a trend.

By analyzing the results obtained from Sen (2003) regarding the break point it can be concluded that in case of rice, cotton and groundnut most of the breaks occur after the introduction of New Agricultural Policy[5]. In case of wheat, jowar, groundnut and Rapeseed/Mustard Oil most of the breaks occurs immediately after green revolution. Also the effect of the introduction of liberalization policy is prominent in case of bajra and jowar. In case of maize most of the break points occur in the decade of 80's.

From the results of Sen (2003) approach one can classify the selected states for each crops into three categories. (1) Good Performer, (2) Moderate Performer and (3) Bad Performer. Now, the results suggest that **(a)** none of the states are good performer for all crops. **(b)** the performance is **moderate** for the following states (i) AP, HA, BI, KA, MP, OR, PU, TN, UP and WB are in case of rice; (ii) In case of wheat BI, HA, PU and UP; (iii) For bajra, GU, HA, KA, MA, RA and UP; (iv) AP, GU, KA, MA, RA and UP for jowar; (v) In case of maize AP, BI, GU, HP, KA, MP, RA and UP; (vi) BI, HA, MA, MP, RA and UP in case of gram; (vii) AP, GU, HA, KA, PU and RA in case of cotton; (viii) for groundnut AP,

[5] New Agricultural Policy was introduced by the central government in July, 2000.

GU, MP and TN; (ix) in case of rapeseed/mustard oil HA, MP, RA, UP and WB and **(c)** the performance is **bad,** for the following states (i) AS in case of rice; (ii) MP and RA in case of wheat; (iii) TN in case of jowar; (iv) PU for maize; (v) in case of cotton MP and MA; (vi) KA for groundnut; (vii) AS and GU in case of rapeseed/mustard oil.

The results of multiple structural break analysis suggest that regional variation is very much prominent among the states and also among the crops. For example in case of rice, for PU and HA breaks occur at mid 70's and mid 80's. On the other hand in case of WB, first break occurs at 1982. In case of wheat, for most of the state first break occurs at late 70's. In case of Bajra break points occur either on early 90's or after 2000. For rest of the crops the occurrences of break points differ from state to state and also from crop to crop.

Another important result is that in case of most of the sample states for all crops one break occurs at 90's decade. These may be due to the introduction of liberalization policies by the central government. The introduction of the New Agricultural Policy, 2000 may affect the crop production because for most of the states one break is found in the first decade of this century in case of all the crops. Thus although there exists a strong regional variation among the states in terms of multiple breaks but any change of policy by the central government may affect the crop production as a whole.

Finally one can found the major determinants of growth for each crop. The results suggest that major determinants of growth vary from crop to crop. But there are some common factors which are (i) Too much rainfall is not good for the growth of output. (ii) Too small holding of land affect the growth of output in the reverse way. (iii) Agricultural loan is significant and positive for almost all crops on the growth of output and also on the growth of HYV uses (iv) Government or Private irrigation, government expenditure on agricultural research and extension and rural literacy has significant positive effect on the growth of output as well as on the growth of HYV uses for almost all crops and (v) Although there exists a non-linear relationship between growth of output and growth of HYV uses the marginal effect of growth of HYV uses is positive implying an increase in growth of HYV uses may increase the growth of output.

Thus Government or Private irrigation, government expenditure on agricultural research and extension, rural literacy and Agricultural loan has positive effect on both growth of output as well as growth of HYV uses. In this present chapter there exists a simultaneous kind of relationship between growth of output and growth of HYV uses. The growth of HYV uses has a positive and significant effect on the growth of output and growth of output in turn positively and significantly affect the growth of HYV uses. Thus the explanatory variables like Government or Private irrigation, government expenditure on agricultural research and extension, rural literacy and Agricultural loan may get the greater importance in the policy suggestion because these variables affect the growth of HYV uses which in turn may push up the growth of output.

Now, if one consider input growth as the explanatory variable, then one point has to be noted that even though there is a non linear relationship between growth of output and growth of labour, the marginal effect of growth of labour is positive implying that although there exists a positive relation between growth of output and growth of employment but after a limit growth of employment may hamper the growth of output. It is the common factor for all the three crops (Rice, Wheat and Jowar). Apart from this growth of fertilizer uses is another major determinant not only for the growth of output but also for the growth of HYV uses.

. ***Thus the analysis reveals that in order to foster growth, any policy changes that will lead to increase in the availability of agricultural loan, government and private irrigation rural literacy, government expenditure on agricultural research and extension should be emphasized. Again the policy of land reform should be implemented effectively so that targeted growth rate may achieve.***

Table-3.1: Results of Unit Root Tests in case of Rice

	ADF		**PP Test**		**KPSS Test**
	ADF STATISTICS	**Prob.***	**Adj. t-Stat**	**Prob.***	**LM-Stat.****
AP	-4.821122	0.0019	-4.818263*	0.0019	0.119908
AS	-5.076953	0.0009	-5.194991*	0.0007	0.126434
BI	-4.251416	0.0087	-4.212531*	0.0096	0.114477
HA	-3.529362	0.0311	-3.529362*	0.0311	0.167646
KA	-5.23572	0.0006	-5.131973*	0.0008	0.080187
MP	-1.659645	0.7505	-1.659645	0.7505	0.260619
OR	-7.395679	0	-7.315292*	0	0.070619
PU	-3.482476	0.0461	-4.363135*	0.0065	0.117414
TN	-3.940243	0.019	-3.94785*	0.0187	0.099881
UP	-3.476933	0.0436	-4.390721*	0.0061	0.011871
WB	-3.379388	0.0682	-3.497172*	0.053	0.093768
***MacKinnon (1996) one-sided p-values.**					
****Kwiatkowski-Phillips-Schmidt-Shin (1992, Table 1)**					

***Significant at 1%, ** Significant at 5%, *** Significant at 10%**

Table-3.2: Results of Trend Analysis in case of Rice

		ADF			PP Test			KPSS test		
	Variable	**Coeff.**	**t-Statistic**	**Prob.**	**Coeff.**	**t-Statistic**	**Prob.**	**Coeff.**	**t-Statistic**	**Prob.**
AP	**C**	6.4853*	4.8448	0.0000	6.4853*	4.8448	0.0000	8.5673*	193.9821	0.0000
	TREND	0.0171*	4.1478	0.0002	0.0171*	4.1478	0.0002	0.0232*	12.4934	0.0000
AS	**C**	6.1566*	5.0920	0.0000	6.1566*	5.0920	0.0000	7.5677*	235.9032	0.0000
	TREND	0.0158*	4.5891	0.0000	0.0158*	4.5891	0.0000	0.0194*	14.4175	0.0000
BI	**C**	5.6446*	4.2448	0.0001	5.6446*	4.2448	0.0001	8.5046*	109.7418	0.0000
	TREND	0.0005*	2.1462	0.0488	0.0005*	2.1462	0.0488	0.0010	9.3217	0.0000
HA	**C**	2.5955*	3.2274	0.0026	2.5955*	3.2274	0.0026	6.3746*	111.8694	0.0000
	TREND	0.0184*	2.7614	0.0088	0.0184*	2.7614	0.0088	0.0495*	20.6967	0.0000
KA	**C**	6.2542*	5.2415	0.0000	6.2542*	5.2415	0.0000	7.4999*	164.6396	0.0000
	TREND	0.0167*	4.4876	0.0001	0.0167*	4.4876	0.0001	0.0196*	10.2716	0.0000
OR	**C**	9.6465*	7.3928	0.0000	9.6465*	7.3928	0.0000	8.1980*	140.9894	0.0000
	TREND	0.0193*	5.3127	0.0000	0.0193*	5.3127	0.0000	0.0157*	6.4229	0.0000
PU	**C**	0.9097*	2.6976	0.0104	0.9097*	2.6976	0.0104	7.3052*	76.6365	0.0000
	TREND	0.0018*	2.1846	0.0456	0.0018*	2.1846	0.0456	0.0589*	14.7116	0.0000
TN	**C**	4.9724*	3.9296	0.0003	4.9724*	3.9296	0.0003	8.5211*	135.7891	0.0000
	TREND	0.0031	2.2870	0.0424	0.0031*	2.2870	0.0424	0.0047***	1.7675	0.0848
UP	**C**	3.4264*	2.3282	0.0256	5.2170*	4.1860	0.0002	8.2713*	132.2051	0.0000
	TREND	0.0129*	2.1790	0.0462	0.0210*	3.6108	0.0009	0.0341*	12.9611	0.0000
WB	**C**	4.1102*	3.4000	0.0016	4.1102*	3.4000	0.0016	8.6400*	212.8127	0.0000
	TREND	0.0129*	3.0833	0.0038	0.0129*	3.0833	0.0038	0.0272*	15.9800	0.0000

***Significant at 1%, ** Significant at 5%, *** Significant at 10%**

Table-3.3: Results of Unit Root Tests in case of Wheat

	ADF		PP Test		KPSS Test
	ADF STATISTICS	**Prob.***	**Adj. t-Stat**	**Prob.***	**LM-Stat.****
BI	-4.730057*	0.0024	-4.873849*	0.0016	0.148757
HA	-4.044419*	0.026	-4.044419*	0.05603	0.112565
MP	-4.181316*	0.0104	-4.352601*	0.0067	0.137617
PU	-5.691122*	0	-5.570637*	0	0.098028
RA	-4.349535*	0.0068	-4.383939*	0.0062	0.121626
UP	-3.295943*	0.0876	-3.295943*	0.0876	0.126139
***MacKinnon (1996) one-sided p-values.**					
****Kwiatkowski-Phillips-Schmidt-Shin (1992, Table 1)**					

***Significant at 1%, ** Significant at 5%, *** Significant at 10%**

Table-3.4: Results of Trend Analysis in case of Wheat

		ADF			PP Test			KPSS test		
	Variable	**Coeff.**	**t-Statistic**	**Prob.**	**Coeff.**	**t-Statistic**	**Prob.**	**Coeff.**	**t-Statistic**	**Prob.**
	C	4.818918*	4.799873	0	4.8188*	4.799873	0	7.61*	140.8239	0
BI	**TREND**	0.012307*	3.406788	0.0016	0.012*	3.406788	0.0016	0.022*	9.984423	0
	C	1.605437*	2.10288	0.0422	1.605*	2.10288	0.0422	7.729*	187.2213	0
HA	**TREND**	0.008***	1.934974	0.0605	0.008*	1.934974	0.0605	0.044*	25.41086	0
	C	5.041138*	4.193721	0.0002	5.041*	4.193721	0.0002	7.856*	133.351	0
MP	**TREND**	0.019626*	3.799278	0.0005	0.019626*	3.799278	0.0005	0.030*	12.23333	0
	C	1.23***	1.759476	0.0865	1.23***	1.759476	0.0865	8.67*	232.8002	0
PU	**TREND**	0.003*	2.242997	0.0215	0.0031*	2.242997	0.0215	0.029*	18.67536	0
	C	5.057*	4.372138	0.0001	5.057*	4.372138	0.0001	7.554*	162.3552	0
RA	**TREND**	0.024*	4.167282	0.0002	0.024*	4.167282	0.0002	0.036*	18.78731	0
	C	1.26827	1.379151	0.1764	1.88*	2.081198	0.0442	9.012*	192.0259	0
UP	**TREND**	0.003473*	2.886807	0.0038	0.0034*	2.886807	0.0038	0.035*	17.94031	0

***Significant at 1%, ** Significant at 5%, *** Significant at 10%**

Table-3.5: Results of Unit Root Tests in case of Bajra

	ADF		PP Test		KPSS Test
	ADF STATISTICS	**Prob.***	**Adj. t-Stat**	**Prob.***	**LM-Stat.****
GU	-3.46476	0.0429	-4.741062*	0.0024	0.085331
HA	-5.682214*	0.0002	-5.685705*	0.0002	0.198972
KA	-5.84069*	0.0001	-5.817897*	0.0001	0.087083
MA	-4.570362*	0.0038	-4.666256*	0.0029	0.183953
RA	-6.62492*	0	-6.646383*	0	0.059134
UP	-5.352593*	0.0004	-5.352593*	0.0004	0.131466
***MacKinnon (1996) one-sided p-values.**					
****Kwiatkowski-Phillips-Schmidt-Shin (1992, Table 1)**					

***Significant at 1%, ** Significant at 5%, *** Significant at 10%**

Table-3.6: Results of Trend Analysis in case of Bajra

		ADF			PP Test			KPSS test		
	Variable	**Coeff.**	**t-Statistic**	**Prob.**	**Coeff.**	**t-Statistic**	**Prob.**	**Coeff.**	**t-Statistic**	**Prob.**
	C	3.06024*	2.389724	0.0222	4.932152*	4.507806	0.0001	7.021323*	51.47527	0
GU	**TREND**	0.001784	0.314716	0.7548	-0.000408	-0.070369	0.9443	-0.002642	-0.461341	0.6471
	C	4.997057*	5.534856	0	4.997057*	5.534856	0	5.865871*	46.13726	0
HA	**TREND**	0.021909*	3.570967	0.001	0.021909*	3.570967	0.001	0.021511*	4.029358	0.0002
	C	5.142231*	5.762217	0	5.142231*	5.762217	0	5.436498*	49.98265	0
KA	**TREND**	0.000209	0.043238	0.9657	0.000209	0.043238	0.9657	-0.000358	-0.078345	0.9379
	C	4.452377*	4.542627	0.0001	4.452377*	4.542627	0.0001	6.275104*	54.24712	0
MA	**TREND**	0.016398*	2.696129	0.0104	0.016398*	2.696129	0.0104	0.021608*	4.448544	0.0001
	C	6.639614*	6.402631	0	6.639614*	6.402631	0	6.642733*	35.22285	0
RA	**TREND**	0.039389*	4.187216	0.0002	0.039389*	4.187216	0.0002	0.034211*	4.320174	0.0001
	C	4.960512*	5.305525	0	4.960512*	5.305525	0	6.31892*	101.922	0
UP	**TREND**	0.019399*	4.783399	0	0.019399*	4.783399	0	0.022191*	8.524308	0

***Significant at 1%, ** Significant at 5%, *** Significant at 10%**

Table-3.7: Results of Unit Root Tests in case of Gram

	ADF		PP Test		KPSS Test
	ADF STATISTICS	**Prob.***	**Adj. t-Stat**	**Prob.***	**LM-Stat.****
BI	-3.66036*	0.0368	-3.705856*	0.0332	0.076445
HA	-4.494878*	0.0046	-4.501149*	0.0045	0.063695
MP	-5.541558*	0.0002	-5.604545*	0.0002	0.110046
MA	-6.197764*	0	-6.201624*	0	0.050419
RA	-4.505836*	0.0045	-4.505836*	0.0045	0.049
UP	-4.524403*	0.0043	-4.573736*	0.0037	0.142143
***MacKinnon (1996) one-sided p-values.**					
****Kwiatkowski-Phillips-Schmidt-Shin (1992, Table 1)**					

***Significant at 1%, ** Significant at 5%, *** Significant at 10%**

Table-3.8: Results of Trend Analysis in case of Gram

		ADF			PP Test			KPSS test		
	Variable	**Coeff.**	**t-Statistic**	**Prob.**	**Coeff.**	**t-Statistic**	**Prob.**	**Coeff.**	**t-Statistic**	**Prob.**
	C	2.689*	3.617	0.0009	2.689*	3.617	0.0009	5.17*	75.5	0
BI	**TREND**	-0.012*	-2.848	0.007	-0.012*	-2.848	0.007	-0.023*	-8.045	0
	C	4.67*	4.371	0.0001	4.67*	4.371	0.0001	6.714*	39.91	0
HA	**TREND**	-0.041*	-3.504	0.0012	-0.041*	-3.504	0.0012	-0.059*	-8.437	0
	C	6.118*	5.574	0	6.118*	5.574	0	6.885*	142.2	0
MP	**TREND**	0.022*	4.783	0	0.022*	4.783	0	0.025*	12.70	0
	C	4.59*	6.228	0	4.59*	6.228	0	4.558*	53.15	0
MA	**TREND**	0.054*	5.635	0	0.054*	5.635	0	0.053*	14.84	0
	C	4.870*	4.454	0.0001	4.870*	4.454	0.0001	7.009*	57.67	0
RA	**TREND**	-0.007*	-1.379	0.1757	-0.007*	-1.379	0.1757	-0.011**	-2.232	0.0312
	C	5.126*	4.498	0.0001	5.126*	4.498	0.0001	7.308*	140.62	0
UP	**TREND**	-0.017*	-3.940	0.0003	-0.017*	-3.940	0.0003	-0.024*	-11.25	0

***Significant at 1%, ** Significant at 5%, *** Significant at 10%**

Table-3.9: Results of Unit Root Tests in case of Jowar

	ADF		PP Test		KPSS Test
	ADF STATISTICS	Prob.*	Adj. t-Stat	Prob.*	LM-Stat.**
AP	-4.82722*	0.0019	-4.797077*	0.002	0.122518
GU	-5.195394*	0.0007	-5.182778*	0.0007	0.081192
KA	-5.805074*	0.0001	-5.804704*	0.0001	0.102765
MA	-3.144289	0.061	-3.896542	0.0541	0.21096
RA	-7.490545*	0	-7.419049*	0	0.125867
TN	-6.799365*	0	-6.765346*	0	0.114762
UP	-6.206284*	0	-5.206946*	0.0006	0.101571
*MacKinnon (1996) one-sided p-values.					
**Kwiatkowski-Phillips-Schmidt-Shin (1992, Table 1)					

***Significant at 1%, ** Significant at 5%, *** Significant at 10%**

Table-3.10: Results of Trend Analysis in case of Jowar

		ADF			PP Test			KPSS test		
	Variable	Coeff.	t-Statistic	Prob.	Coeff.	t-Statistic	Prob.	Coeff.	t-Statistic	Prob.
AP	C	4.937*	4.8326	0.0000	4.937*	4.8326	0.0000	7.3449*	126.264	0.0000
	TREND	-0.023*	-4.6260	0.0000	-0.02*	-4.6260	0.0000	-0.0321*	-13.15	0.0000
GU	C	5.0598*	4.8632	0.0000	5.059*	4.8632	0.0000	6.1108*	19.060	0.0000
	TREND	-0.026***	-1.7317	0.0914	-0.026***	-1.7317	0.0914	-0.0319**	-2.36	0.0229
KA	C	7.092*	5.7914	0.0000	7.092*	5.7914	0.0000	7.4832*	130.51	0.0000
	TREND	-0.0046***	-1.7507	0.0881	-0.004**	-1.7507	0.0881	-0.0053**	-2.220	0.0321
MA	C	3.048*	3.2597	0.0024	3.048*	3.2597	0.0024	8.2534*	70.278	0.0000
	TREND	-0.0030	-0.8335	0.4098	-0.0030	-0.8335	0.4098	0.0040	0.8078	0.4240
RA	C	6.827*	7.2891	0.0000	6.827*	7.2891	0.0000	5.7683*	39.726	0.0000
	TREND	-0.0081	-1.2548	0.2172	-0.0081	-1.2548	0.2172	-0.0082	-1.34	0.1849
TN	C	2.132*	2.7995	0.0080	2.132*	2.7995	0.0080	6.6368*	82.24	0.0000
	TREND	-0.0097*	-2.4664	0.0183	-0.009*	-2.4664	0.0183	-0.0269*	-7.93	0.0000
UP	C	3.049*	2.2338	0.0322	5.04*	5.0302	0.0000	6.2614*	72.10	0.0000
	TREND	-0.013*	-2.3753	0.0233	-0.016*	-3.3365	0.0019	-0.0200*	-5.48	0.0000

***Significant at 1%, ** Significant at 5%, *** Significant at 10%**

Table-3.11: Results of Unit Root Tests in case of Maize

	ADF		PP Test		KPSS Test
	ADF STATISTICS	**Prob.***	**Adj. t-Stat**	**Prob.***	**LM-Stat.****
AP	-3.5153*	0.0319	-3.4675*	0.0341	0.1123
BI	-7.3438*	0.0000	-7.7964*	0.0000	0.0696
GU	-6.0191*	0.0001	-6.0191*	0.0001	0.1340
HP	-5.8297*	0.0001	-5.8511*	0.0001	0.0819
KA	-3.6640*	0.0390	-2.3533*	0.0397	0.1496
MP	-4.3993*	0.0059	-4.4108*	0.0058	0.1672
PU	-7.1845*	0.0000	-7.2155*	0.0000	0.1050
RA	-4.8677*	0.0017	-4.8001*	0.0020	0.1468
UP	-5.4599*	0.0003	-5.4984*	0.0003	0.1201
***MacKinnon (1996) one-sided p-values.**					
****Kwiatkowski-Phillips-Schmidt-Shin (1992, Table 1)**					

***Significant at 1%, ** Significant at 5%, *** Significant at 10%**

Table-3.12: Results of Trend Analysis in case of Maize

		ADF			PP Test			KPSS test		
	Variable	**Coeff.**	**t-Statistic**	**Prob.**	**Coeff.**	**t-Statistic**	**Prob.**	**Coeff.**	**t-Statistic**	**Prob.**
AP	**C**	1.5536*	2.5237	0.0159	1.5536*	2.5237	0.0159	5.5103*	68.6050	0.0000
	TREND	0.0194*	2.6896	0.0106	0.0194*	2.6896	0.0106	0.0616*	18.2651	0.0000
BI	**C**	6.3787*	7.5608	0.0000	7.8119*	7.9949	0.0000	6.4612*	68.7971	0.0000
	TREND	0.0224*	5.0864	0.0000	0.0353*	6.1559	0.0000	0.0272*	6.8937	0.0000
GU	**C**	4.8647*	5.8860	0.0000	4.8647*	5.8860	0.0000	5.3155*	40.3360	0.0000
	TREND	0.0367*	4.6249	0.0000	0.0367*	4.6249	0.0000	0.0364*	6.5776	0.0000
HP	**C**	5.5126*	5.8276	0.0000	5.5126*	5.8276	0.0000	6.0286*	186.5598	0.0000
	TREND	0.0145*	5.2040	0.0000	0.0145*	5.2040	0.0000	0.0152*	11.2347	0.0000
KA	**C**	2.8819*	3.7364	0.0010	1.2608*	2.3223	0.0257	5.4585*	77.3947	0.0000
	TREND	0.0440*	3.5905	0.0015	0.0141*	2.0465	0.0477	0.0658*	22.2250	0.0000
MP	**C**	4.4019*	4.4191	0.0001	4.4019*	4.4191	0.0001	6.3548*	113.7434	0.0000
	TREND	0.0167*	3.6492	0.0008	0.0167*	3.6492	0.0008	0.0240*	10.2172	0.0000
PU	**C**	0.0421	0.0692	0.9452	0.9145	1.5153	0.1380	6.5652*	84.6664	0.0000
	TREND	-0.0054*	-2.0305	0.0502	-0.0001	-0.0583	0.9538	-0.0172*	-5.2976	0.0000
RA	**C**	4.4135*	4.8008	0.0000	4.4135	4.8008*	0.0000	6.2510*	71.8841	0.0000
	TREND	0.0225*	4.2287	0.0001	0.0225	4.2287*	0.0001	0.0281*	7.7022	0.0000
UP	**C**	5.4768*	5.4125	0.0000	5.4768	5.4125*	0.0000	6.9840*	113.0652	0.0000
	TREND	0.0055*	2.1505	0.0379	0.0055	2.1505*	0.0379	0.0048*	1.8370	0.0736

Significant at 1%, ** Significant at 5%, *** Significant at 10%

Table-3.13: Results of Unit Root Tests in case of Cotton

	ADF		PP Test		KPSS Test
	ADF STATISTICS	**Prob.***	**Adj. t-Stat**	**Prob.***	**LM-Stat.****
AP	-6.125246*	0	-6.100039*	0	0.126106
GU	-7.482814*	0	-7.305325*	0	0.115662
HA	-4.140552*	0.0116	-4.14687*	0.0114	0.111704
KA	-3.501206*	0.0525	-3.505412*	0.052	0.06548
MA	-4.892096*	0.0016	-4.987978*	0.0012	0.106955
MP	-7.778159	0	-7.425929	0	0.150644
PU	-5.571301*	0	-5.655467*	0	0.062168
RA	-3.93765*	0.0192	-4.003963*	0.0163	0.1206
***MacKinnon (1996) one-sided p-values.**					
****Kwiatkowski-Phillips-Schmidt-Shin (1992, Table 1)**					

Significant at 1%, ** Significant at 5%, *** Significant at 10%

Table-3.14: Results of Trend Analysis in case of Cotton

		ADF			PP Test			KPSS test		
	Variable	**Coeff.**	**t-Statistic**	**Prob.**	**Coeff.**	**t-Statistic**	**Prob.**	**Coeff.**	**t-Statistic**	**Prob.**
AP	**C**	2.1081*	3.2757	0.0023	2.1081*	3.2757	0.0023	5.2679*	58.1315	0.0000
	TREND	0.0278*	2.8621	0.0068	0.0278*	2.8621	0.0068	0.0756*	19.8639	0.0000
GU	**C**	2.0409*	2.3896	0.0219	2.0409*	2.3896	0.0219	6.9689*	41.5130	0.0000
	TREND	0.0155*	2.2459	0.0306	0.0155*	2.2459	0.0306	0.0385*	5.4656	0.0000
HA	**C**	3.8216*	4.1765	0.0002	3.8216*	4.1765	0.0002	6.0100*	96.8966	0.0000
	TREND	0.0254*	3.8631	0.0004	0.0254*	3.8631	0.0004	0.0405*	15.5361	0.0000
KA	**C**	3.3175*	3.4673	0.0013	3.3175*	3.4673	0.0013	6.4035*	71.7274	0.0000
	TREND	0.0039	1.0802	0.2869	0.0039	1.0802	0.2869	0.0058	1.5567	0.1274
MA	**C**	5.1487*	4.9176	0.0000	5.1487*	4.9176	0.0000	6.5259*	78.4453	0.0000
	TREND	0.0396*	4.5328	0.0001	0.0396*	4.5328	0.0001	0.0505*	14.4605	0.0000
MP	**C**	1.1643***	1.6946	0.0983	1.1643***	1.6946	0.0983	5.3035*	53.4617	0.0000
	TREND	0.0116	0.3159	0.261	0.0116	0.3159	0.261	0.0340	1.1651	0.1862
PU	**C**	2.1012*	2.5578	0.0146	2.1012*	2.5578	0.0146	7.0469*	72.8535	0.0000
	TREND	0.0046	1.3507	0.1848	0.0046	1.3507	0.1848	0.0132*	3.2551	0.0023
RA	**C**	3.5756*	3.9078	0.0004	3.5756*	3.9078	0.0004	6.0204*	47.3532	0.0000
	TREND	0.0112**	1.9405	0.0598	0.0112**	1.9405	0.0598	0.0185*	3.4701	0.0013

Significant at 1%, ** Significant at 5%, *** Significant at 10%

Table-3.15: Results of Unit Root Tests in case of Groundnut

	ADF		PP Test		KPSS Test
	ADF STATISTICS	Prob.*	Adj. t-Stat	Prob.*	LM-Stat.**
AP	-4.342507*	0.0069	-4.655168*	0.003	0.180147
GU	-5.837267*	0.0031	-5.713976*	0.0001	0.123652
KA	-6.831427*	0	-3.79742*	0.0268	0.171732
MP	-3.218293***	0.0951	-3.218293***	0.0951	0.110613
TN	-3.689382***	0.0875	-3.155777***	0.0976	0.162833
***MacKinnon (1996) one-sided p-values.**					
****Kwiatkowski-Phillips-Schmidt-Shin (1992, Table 1)**					

Significant at 1%, ** Significant at 5%, *** Significant at 10%

Table-3.16: Results of Trend Analysis in case of Groundnut

		ADF			PP Test			KPSS test		
	Variable	Coeff.	t-Statistic	Prob.	Coeff.	t-Statistic	Prob.	Coeff.	t-Statistic	Prob.
AP	**C**	5.0149*	4.3607	0.0001	5.0149*	4.3607	0.0001	7.1319*	63.4422	0.0000
	TREND	0.0027	0.5372	0.5943	0.0027	0.5372	0.5943	0.0052	1.1063	0.2752
GU	**C**	3.8543*	2.7321	0.0097	6.0037*	5.4101	0.0000	6.8422*	33.3536	0.0000
	TREND	0.0171***	1.7656	0.0859	0.0203**	2.1427	0.0386	0.0200*	2.3222	0.0254
KA	**C**	1.9051***	1.8492	0.0727	3.4353*	3.5918	0.0009	6.5318*	63.5465	0.0000
	TREND	-0.0007	-0.1797	0.8584	-0.0003	-0.0653	0.9482	0.0017	0.3885	0.6997
MP	**C**	2.4214*	3.1448	0.0032	2.4214*	3.1448	0.0032	5.5201*	87.3771	0.0000
	TREND	0.0013	0.5516	0.5844	0.0013	0.5516	0.5844	-0.0012	-0.4491	0.6558
TN	**C**	1.6710***	1.6981	0.0981	3.2058*	3.3888	0.0016	7.0254*	88.9368	0.0000
	TREND	-0.0006	-0.2348	0.8157	-0.0007	-0.2563	0.7991	0.0003	0.0944	0.9253

Significant at 1%, ** Significant at 5%, *** Significant at 10%

Table-3.17: Results of Unit Root Tests in case of Rapeseed/Mustard Oil

	ADF		PP Test		KPSS Test
	ADF STATISTICS	Prob.*	Adj. t-Stat	Prob.*	LM-Stat.**
AS	-6.1275*	0.0000	-6.0507*	0.0000	0.1131
GU	-4.8421*	0	-4.6196*	0	0.1141
HA	-6.1560*	0	-3.2793***	0.0840	0.1502
MP	-3.5574*	0.0464	-3.6884*	0.0345	0.1438
RA	-7.8327*	0.0000	-7.7667*	0.0000	0.1590
UP	-3.9408*	0.0190	-4.0483*	0.0146	0.0829
WB	-6.4456*	0.0000	-6.5140*	0.0000	0.1265
***MacKinnon (1996) one-sided p-values.**					
****Kwiatkowski-Phillips-Schmidt-Shin (1992, Table 1)**					

Significant at 1%, ** Significant at 5%, *** Significant at 10%

Table-3.18: Results of Trend Analysis in case of Rapeseed/Mustard Oil

		ADF			PP Test			KPSS test		
	Variable	**Coeff.**	**t-Statistic**	**Prob.**	**Coeff.**	**t-Statistic**	**Prob.**	**Coeff.**	**t-Statistic**	**Prob.**
AS	**C**	0.8549*	2.2667	0.0292	0.8549*	2.2667	0.0292	4.4009*	56.9685	0.0000
	TREND	0.0019	0.7734	0.4441	0.0019	0.7734	0.4441	0.0185*	5.7000	0.0000
GU	**C**	0.7075*	2.3716	0.0229	0.7075*	2.3716	0.0229	3.5082*	20.2434	0.0000
	TREND	0.0082*	2.0205	0.0031	0.0082*	2.0205	0.0031	0.0824*	11.3261	0.0000
HA	**C**	1.8740*	3.2322	0.0025	1.8740*	3.2322	0.0025	4.3059*	34.5725	0.0000
	TREND	0.0311*	2.7986	0.0080	0.0311*	2.7986	0.0080	0.0735*	14.0474	0.0000
MP	**C**	2.2584*	3.6774	0.0007	2.2584*	3.6774	0.0007	4.3654*	37.6441	0.0000
	TREND	0.0304*	2.9876	0.0049	0.0304*	2.9876	0.0049	0.0637*	13.0828	0.0000
RA	**C**	1.7972*	2.8999	0.0062	1.7972*	2.8999	0.0062	5.0157*	36.0899	0.0000
	TREND	0.0329*	2.6142	0.0127	0.0329*	2.6142	0.0127	0.0919*	15.7465	0.0000
UP	**C**	3.8055*	3.9030	0.0004	3.8055*	3.9030	0.0004	6.9194*	117.6138	0.0000
	TREND	-0.0014	-0.5903	0.5585	-0.0014	-0.5903	0.5585	-0.0042***	-1.7165	0.0938
WB	**C**	0.5265*	1.7634	0.0859	0.5265*	1.7634	0.0859	3.7377*	31.0910	0.0000
	TREND	0.0060	0.9736	0.3364	0.0060	0.9736	0.3364	0.0677*	13.4209	0.0000

Significanat 1%, ** Significant at 5%, *** Significant at 10%

Table-3.19: Criterion of Good, Moderate and Bad Performer:

<table>
<tr><th>Good</th><th>Moderate</th><th>Bad</th></tr>
<tr><td rowspan="7">T is positive and Significant
DU and DT are also positive and Significant</td><td>T is positive and Significant
DU and DT are insignificant</td><td>T is negative and Significant
DU and DT are negative and Significant</td></tr>
<tr><td>T is positive and Significant
Among DU or DT one is positive and significant and other is insignificant</td><td>T is insignificant
DU and DT are insignificant</td></tr>
<tr><td>T is positive and Significant
Among DU or DT one is positive and significant and other is negative and significant</td><td>T is insignificant
DU and DT are negative and Significant</td></tr>
<tr><td>T is positive and Significant
DU and DT are negative and significant</td><td rowspan="4">T is insignificant
DU or DT is negative and Significant</td></tr>
<tr><td>T is insignificant
DU or DT is positive and significant</td></tr>
<tr><td>T is negative and Significant
DU and DT is positive and significant</td></tr>
<tr><td>T is negative and Significant
Among DU or DT one is positive and significant and other is negative and significant</td></tr>
</table>

Table-3.20: Nature of the Series Food Crops

STATES	F-statistic	YEAR	NATURE OF THE SERIES	STATES	F-statistic	YEAR	NATURE OF THE SERIES
RICE				**MAIZE**			
AP	21.43588*	2004	TS	**AP**	15.40548*	1984	TS
AS	32.54033*	2006	TS	**BI**	64.94399*	1994	TS
BI	18.91655*	2006	TS	**GU**	25.91586*	1987	TS
HA	23.07906*	1976	TS	**HP**	18.23896*	1976	TS
KA	19.21963*	1994	TS	**KA**	25.78969*	1989	TS
MP	62.71968*	2000	TS	**MP**	16.58089*	1984	TS
OR	39.49739*	2004	TS	**PU**	21.71215*	1990	TS
PU	22.73299*	1979	TS	**RA**	15.41389*	1986	TS
TN	19.84546*	2004	TS	**UP**	19.13888*	1987	TS
UP	29.89355*	1987	TS				
WB	26.63132*	1983	TS				
WHEAT				**JOWAR**			
BI	22.76091*	1985	TS	**AP**	27.16977*	1988	TS
HA	26.01637*	1975	TS	**GU**	31.24186*	1983	TS
MP	25.00145*	1995	TS	**KA**	23.37814*	1976	TS
PU	18.04634*	1975	TS	**MA**	29.02226*	1976	TS
RA	22.23185*	1998	TS	**RA**	42.78036*	2006	TS
UP	40.49822*	1975	TS	**TN**	13.13084*	1991	TS
BAZRA				**UP**	25.63827*	1995	TS
GU	38.82069*	1991	TS	**GRAM**			
HA	34.76342*	1989	TS	**BI**	30.16649*	2002	TS
KA	25.07745*	1976	TS	**HA**	15.90609*	2000	TS
MA	23.61886*	1976	TS	**MA**	34.18114*	1986	TS
RA	37.50356*	1991	TS	**MP**	25.7588*	1979	TS
GU	38.82069*	1991	TS	**RA**	16.30517*	2000	TS
UP	21.22581*	1981	TS	**UP**	20.96533*	1986	TS

Significanat 1%, ** Significant at 5%, *** Significant at 10%

Table-3.21: Amit Sen's Results Rice

	AP		AS		BI		HR	
	Coefficient	**t-Statistic**	**Coefficient**	**t-Statistic**	**Coefficient**	**t-Statistic**	**Coefficient**	**t-Statistic**
C	-1.64492	-1.10871	-1.51496	-1.37908	-2.21788	-1.54059	2.778132	2.943319*
DU	0.228547	2.483932*	-0.234856	-2.798455*	0.434458	2.42419*	0.350022	3.030247*
T	-0.00787	-1.64174***	-0.00544	-1.71329***	-0.00554	-1.11073	0.00805	0.200911
DT	-0.02246	-1.43756	-0.04799	-1.68517***	-0.05015	-1.25109	0.008349	0.205133
Y1	0.201514	1.154537	0.206643	1.413024	0.270209	1.582165	-0.45457	-3.05416*
D1LNY	0.580156	7.191848*	0.577965	9.112216*	0.659372	7.292543*	0.37674	5.487395*
	KR		**MP**		**OR**		**PU**	
	Coefficient	**t-Statistic**	**Coefficient**	**t-Statistic**	**Coefficient**	**t-Statistic**	**Coefficient**	**t-Statistic**
C	0.059299	0.044105	5.041521	4.118904*	0.020401	0.013235	0.139218	0.243253
DU	0.212065	2.317222*	-1.23309	-0.07656	0.229361	2.21058*	0.16848	2.80521*
T	-0.0012	-0.28664	0.018041	3.410549*	-0.00096	-0.25314	0.030648	1.703382***
DT	-0.02914	-1.14569	0.020723	1.335657	-0.04001	-0.12801	-0.03231	-2.12356*
Y1	-0.00396	-0.02192	-0.63777	-4.12913*	0.00028	0.001483	-0.02014	-0.22017
D1LNY	0.497808	5.958025*	0.278344	4.635698*	0.510015	7.636553*	0.455399	6.594098*
	TN		**UP**		**WB**			
	Coefficient	**t-Statistic**	**Coefficient**	**t-Statistic**	**Coefficient**	**t-Statistic**		
C	-2.64161	-1.97531**	1.787283	1.549004	0.960862	0.978325		
DU	0.387405	3.018632*	0.224139	2.448805*	0.179778	3.692825*		
T	-0.00662	-2.28388*	-0.00555	-0.37013	-0.0084	-1.38144		
DT	-0.03132	-1.54499	0.006758	0.470803	0.006577	0.986492		
Y1	0.318869	2.010395*	-0.21047	-1.47815	-0.10376	-0.9223		
D1LNY	0.610409	7.765931*	0.459975	7.704444*	0.455087	6.933538*		

Significant at 1%, ** Significant at 5%, *** Significant at 10%

Table-3.22: Amit Sen's Results Wheat

	BI		HA		MP	
	Coefficient	**t-Statistic**	**Coefficient**	**t-Statistic**	**Coefficient**	**t-Statistic**
C	1.993199	2.482133*	1.072245	2.107802*	2.103629	1.255396
DU	0.443068	5.359304*	0.237018	5.007649*	-0.29487	-3.051*
T	-0.41971	-6.15406*	-0.03695	-1.1321	0.014979	1.474625
DT	0.419203	6.16006*	0.040292	1.218754	0.01364	1.213861
Y1	-0.03713	-0.36959	-0.13065	-2.10715*	-0.27736	-1.25846
D1LNY	0.610629	8.451002*	0.48696	7.804236*	0.400635	4.47666*
	PU		**RA**		**UP**	
	Coefficient	**t-Statistic**	**Coefficient**	**t-Statistic**	**Coefficient**	**t-Statistic**
C	0.651397	1.309017	-0.67455	-0.48709	1.400318	2.743325*
DU	0.103483	2.739514*	-0.13896	-2.1505*	0.215132	4.553607*
T	-0.01408	-0.5399	-0.00191	-0.21838	-0.02201	-0.71783
DT	0.014243	0.545274	0.010282	1.105263	0.024652	0.797419
Y1	-0.07033	-1.24141	0.093339	0.496891	-0.15428	-2.84488*
D1LNY	0.473228	7.401365*	0.535539	6.793606*	0.485726	11.21004*

Significant at 1%, ** Significant at 5%, *** Significant at 10%

Table-3.23: Amit Sen's Results Bajra

	GU		HA		KR	
	Coefficient	**t-Statistic**	**Coefficient**	**t-Statistic**	**Coefficient**	**t-Statistic**
C	0.487991	0.544534	0.136041	0.09178	-2.61217	-1.99371**
DU	0.462819	3.252293*	0.270821	1.782048***	-0.72724	-2.84698*
T	-0.01846	-1.64882***	-0.00709	-0.51213	0.587406	3.34235*
DT	0.00512	0.361603	0.002957	0.129502	-0.58509	-3.3261*
Y1	-0.05276	-0.4416	-0.02368	-0.10115	0.066356	0.291964
D1LNY	0.478252	9.108085*	0.483358	6.026968*	0.545262	5.897239*
	MA		**RA**		**UP**	
	Coefficient	**t-Statistic**	**Coefficient**	**t-Statistic**	**Coefficient**	**t-Statistic**
C	-2.51833	-2.46058*	1.01777	0.642656	0.235883	0.19932
DU	-0.81125	-3.71043*	0.40188	1.665704***	0.215946	2.312878*
T	0.687771	4.127222*	-0.00733	-0.41938	-0.0321	-1.6152
DT	-0.68799	-4.13708*	0.005019	0.181184	0.031416	1.461276
Y1	-0.01429	-0.09985	-0.14827	-0.6773	-0.01173	-0.06605
D1LNY	0.553766	7.65764*	0.452475	6.040825*	0.456351	5.868324*

Significant at 1%, ** Significant at 5%, *** Significant at 10%

Table-3.24: Amit Sen's Results Jowar

	AP		GU		KA	
	Coefficient	**t-Statistic**	**Coefficient**	**t-Statistic**	**Coefficient**	**t-Statistic**
C	1.11949	1.006071	0.266154	0.244707	-1.27348	-0.80887
DU	0.191216	2.138604*	1.523676	3.743964*	-0.27016	-2.03223*
T	-0.08024	-2.51833*	-0.06802	-2.20548*	0.285024	3.035689*
DT	0.07426	2.247767*	0.023132	0.609153	-0.28522	-3.03866*
Y1	-0.10111	-0.64435	0.045594	0.298808	0.015356	0.074783
D1LNY	0.491162	7.043554*	0.480565	7.293979*	0.511981	5.935027*
	MA		**RA**		**TN**	
	Coefficient	**t-Statistic**	**Coefficient**	**t-Statistic**	**Coefficient**	**t-Statistic**
C	-0.59728	-0.63742	-0.35309	-0.29757	-0.05999	-0.0606
DU	-0.40536	-2.33767*	-1.33098	-2.96377*	-0.20274	-2.44616*
T	0.345597	3.333741*	0.003598	0.716814	0.004249	0.683343
DT	-0.34962	-3.36325*	0.669269	3.272726*	0.003316	0.264938
Y1	-0.07713	-0.6177	0.049515	0.243902	0.005921	0.037554
D1LNY	0.472851	7.832803*	0.519491	7.304824*	0.496477	5.374268*
	UP					
	Coefficient	**t-Statistic**				
C	2.305324	1.952775**				
DU	0.404669	2.91264*				
T	-0.05545	-2.50076*				
DT	0.040711	1.804082***				
Y1	-0.32202	-1.68841***				
D1LNY	0.383632	4.947401*				

Significant at 1%, ** Significant at 5%, *** Significant at 10%

Table-3.25: Amit Sen's Results Maize

	AP		BI		GU		HP	
	Coefficient	**t-Statistic**	**Coefficient**	**t-Statistic**	**Coefficient**	**t-Statistic**	**Coefficient**	**t-Statistic**
C	1.356833	1.845495**	3.278408	3.609626*	-1.12956	-0.79494	-0.02366	-0.02158
DU	-0.25895	-2.6165*	0.297607	2.370645*	-0.29732	-1.121	-0.14503	-2.05675*
T	0.022778	1.790525***	-0.58162	-4.55227*	0.25237	1.902223**	0.106644	1.986183**
DT	0.00236	0.1955	0.582713	4.629371*	-0.24998	-1.85218***	-0.10569	-1.98259**
Y1	-0.24315	-1.88477**	-0.09368	-0.57745	-0.0167	-0.08039	-0.05808	-0.31388
D1LNY	0.39108	4.845248*	0.212164	3.805473*	0.482455	5.902813*	0.459876	5.653813*
	KA		**MP**		**PU**		**RA**	
	Coefficient	**t-Statistic**	**Coefficient**	**t-Statistic**	**Coefficient**	**t-Statistic**	**Coefficient**	**t-Statistic**
C	1.418435	2.699305*	-0.25773	-0.21624	-0.54163	-0.39231	1.426413	1.136352
DU	0.080832	1.021021	0.15896	1.93404**	0.118916	1.474055	-0.34913	-2.45006*
T	-0.07622	-4.17912*	0.013627	1.089298	-0.00168	-0.16399	0.038946	2.398299*
DT	0.089548	5.231046*	-0.01321	-1.19505	0.00205	0.146803	-0.02198	-1.42508
Y1	-0.15249	-1.66325	0.029696	0.152009	0.078011	0.395808	-0.26983	-1.33534
D1LNY	0.457385	7.910313*	0.508096	5.669978*	0.524049	6.222743*	0.400769	4.093286*
	UP							
	Coefficient	**t-Statistic**						
C	-0.51723	-0.46782						
DU	-0.17527	-2.08449*						
T	0.017831	2.25709*						
DT	-0.01673	-1.96687**						
Y1	0.052994	0.332069						
D1LNY	0.488978	6.865201*						

Significant at 1%, ** Significant at 5%, *** Significant at 10%

Table-3.26: Amit Sen's Results Gram

	BI		HA		MA	
	Coefficien	**t-Statistic**	**Coefficient**	**t-Statistic**	**Coefficient**	**t-Statistic**
C	0.80585	0.988291	1.309817	0.935668	-1.99407	-2.147*
DU	-0.29838	-2.91039*	0.63745	1.83802***	-0.5643	-3.22828*
T	1.46E-06	0.000556	-0.00484	-0.39905	0.53041	4.225546*
DT	0.025004	2.232281*	0.050581	1.633761	-0.52961	-4.24298*
Y1	-0.16739	-1.02844	-0.21123	-0.99466	-0.01143	-0.0616
D1LNY	0.435464	6.236526*	0.419497	4.268751*	0.491201	6.556811*
	MP		**PU**		**RA**	
	Coefficient	**t-Statistic**	**Coefficient**	**t-Statistic**	**Coefficient**	**t-Statistic**
C	0.31713	0.285574	-1.04992	-1.09313	0.505018	0.437604
DU	0.148835	1.802923***	0.325182	1.899034***	0.4852	2.45103*
T	-0.03825	-1.55639	-0.02309	-0.95315	0.006098	0.887161
DT	0.037505	1.510176	0.052912	2.658091*	0.033923	1.566774
Y1	-0.0157	-0.09928	0.207229	1.369031	-0.084	-0.508
D1LNY	0.488528	7.286367*	0.607222	6.163655*	0.463917	5.430458*
	UP					
	Coefficient	**t-Statistic**				
C	0.779104	0.660685				
DU	0.244931	2.228374*				
T	-0.09005	-1.12311				
DT	0.086491	1.089777				
Y1	-0.07747	-0.52792				
D1LNY	0.478563	6.719774*				

Significant at 1%, ** Significant at 5%, *** Significant at 10%

Table-3.27: Nature of the Series Non-Food Crops

STATES	F-statistic	YEAR	NATURE OF THE SERIES	STATES	F-statistic	YEAR	NATURE OF THE SERIES
COTTON				GROUNDNUT			
AP	13.74648*	1996	TS	AP	25.81887*	1978	TS
GU	12.86483*	1999	TS	GU	43.34496*	2001	TS
HA	18.22866*	2004	TS	KA	30.07818*	1991	TS
KA	20.53156*	2005	TS	MP	12.89686*	1977	TS
MP	20.69743*	2011	TS	TN	29.70058*	2006	TS
MA	18.08383*	1995	TS				
PU	11.85244*	2000	TS				
RA	15.91827*	1990	TS				
REPSEED AND MUSTER OIL							
AS	17.0635*	1981	TS				
GU	18.52542*	1985	TS				
HA	23.75654*	1981	TS				
MP	16.95276*	1979	TS				
RA	18.26959*	1978	TS				
UP	15.08033*	1989	TS				
WB	20.59057*	1978	TS				

Significant at 1%, ** Significant at 5%, *** Significant at 10%

Table-3.28: Amit Sen's Results Cotton

	AP		GU		HA		KA	
	Coefficient	t-Statistic	Coefficient	t-Statistic	Coefficient	t-Statistic	Coefficient	t-Statistic
C	0.169758	0.235765	-0.77434	-0.59792	-0.687	-0.78276	-2.25946	-2.19842*
DU	0.23876	2.09637*	0.492805	2.437705*	0.322951	2.929339*	0.630089	3.54782*
T	0.010493	0.390425	-0.02392	-1.54759	-0.00977	-1.4544	-0.00752	-2.31142*
DT	-0.00241	-0.12779	0.009581	0.375281	-0.03053	-1.74781	-0.06204	-1.90753***
Y1	-0.01934	-0.12114	0.128358	0.761663	0.133342	0.90086	0.364871	2.277242*
D1LNY	0.50069	5.502886*	0.517756	5.476971*	0.587434	7.109011*	0.623896	7.691488*
	MP		MA		PU		RA	
	Coefficient	t-Statistic	Coefficient	t-Statistic	Coefficient	t-Statistic	Coefficient	t-Statistic
C	-0.12241	-0.20123	0.614182	0.438883	-1.87783	-2.0466*	0.023401	0.025308
DU	0.339045	0.986997	-0.17412	-1.22693	0.527769	3.485321*	1.22346	2.83764*
T	0.002044	0.568802	0.004782	0.42807	-0.01213	-2.57773*	-0.00084	-0.15929
DT	-0.00512	-0.0237	0.020796	1.373956	0.03101	1.95523**	0.66445	3.467284*
Y1	0.018135	0.159557	-0.08691	-0.4054	0.282244	2.151012*	0.002234	0.014455
D1LNY	0.507638	6.654194*	0.473535	5.033539*	0.589356	6.326449*	0.501569	5.670852*

Significant at 1%, ** Significant at 5%, *** Significant at 10%

Table-3.29: Amit Sen's Results Groundnuts

	AP		GU		KA	
	Coefficient	**t-Statistic**	**Coefficient**	**t-Statistic**	**Coefficient**	**t-Statistic**
C	-0.49947	-0.41245	-1.48582	-1.47387	-0.40581	-0.32395
DU	0.381545	2.643127*	-0.79412	-2.62125*	-0.21186	-1.61406
T	-0.09183	-1.79341***	0.343999	3.038164*	0.010738	1.111054
DT	0.080916	1.55654	-0.33838	-2.98817*	-0.00655	-0.37371
Y1	0.1259	0.75845	-0.02976	-0.23671	0.048551	0.237732
D1LNY	0.542535	7.450771*	0.493808	9.579686*	0.517424	6.661863*
	MP		**TN**			
	Coefficient	**t-Statistic**	**Coefficient**	**t-Statistic**		
C	-0.39324	-0.47381	-0.81044	-1.20407		
DU	-0.3062	-2.64226*	0.244726	2.197654*		
T	0.13744	2.493946*	-0.00421	-1.86632***		
DT	-0.13409	-2.43188*	-0.02066	-0.964		
Y1	-0.03468	-0.24908	0.124201	1.275715		
D1LNY	0.462274	4.99522*	0.523997	10.30163*		

Significant at 1%, ** Significant at 5%, *** Significant at 10%

Table-3.30: Amit Sen's Results Rapeseed/Mustard Oil

	AS		GU		HA		MP	
	Coefficient	**t-Statistic**	**Coefficient**	**t-Statistic**	**Coefficient**	**t-Statistic**	**Coefficient**	**t-Statistic**
C	0.000427	0.000869	-0.36237	-1.058	0.458625	0.869901	0.815545	1.303765
DU	-0.17125	-3.19296*	-0.47238	-2.87515*	0.317136	1.885268***	0.519763	2.892678*
T	0.003083	0.339117	0.007569	0.273758	-0.00475	-0.15778	-0.13079	-2.45002*
DT	0.002897	0.275245	-0.01147	-0.45953	0.004445	0.140485	0.127511	2.359366*
Y1	0.006435	0.050563	0.139127	1.00296	-0.10383	-0.97316	-0.02678	-0.22565
D1LNY	0.494013	6.37709*	0.557752	7.150045*	0.459042	7.60922*	0.518166	7.103271*
	RA		**UP**		**WB**			
	Coefficient	**t-Statistic**	**Coefficient**	**t-Statistic**	**Coefficient**	**t-Statistic**		
C	0.494963	0.863343	1.105618	1.019627	0.647645	2.481405*		
DU	0.473603	2.642862*	0.186567	2.356584*	0.415626	4.198493*		
T	-0.07458	-1.14563	-0.0121	-1.52874	-0.08515	-2.46978*		
DT	0.071402	1.079545	0.007458	0.875698	0.083536	2.401653*		
Y1	-0.0404	-0.46513	-0.14732	-0.98079	-0.06764	-1.356		
D1LNY	0.456667	7.268154*	0.420224	5.156288*	0.419954	6.825748*		

Significant at 1%, ** Significant at 5%, *** Significant at 10%

Table-3.31: Overall Performance of the Crops

	Performance			Over All Performance of the Crops
Crops	**Good**	**Moderate**	**Bad**	
Rice	Nil	AP, HA, BI, KA, MP, OR, PU, TN, UP and WB	AS	Moderate
Wheat	Nil	BI, HA, PU and UP	MP and RA	Moderate
Bajra	Nil	GU, HA, KA, MA, RA and UP	Nil	Moderate
Jowar	Nil	AP, GU, KA, MA, RA and UP	TN	Moderate
Maize	Nil	AP, BI, GU, HP, KA, MP, RA and UP	PU	Moderate
Gram	Nil	BI, HA, MA, MP, PU, RA and UP	Nil	Moderate
Cotton	Nil	AP, GU, HA, KA, PU and RA	MP and MA	Moderate
Groundnut	Nil	AP, GU, MP and TN	KA	Moderate
Rapeseed/Mustard Oil	Nil	HA, MP, RA, UP and WB	AS and GU	Moderate

Table-3.32: Performance of Rice State –wise:

States	Overall Trend	Change in the Level after the Break	Change in the Growth after the Break	Performance
AP	Negative and Significant	Positive and Significant	Negative and insignificant	Moderate
AS	Negative and Significant	Negative and Significant	Negative and Significant	Bad
BI	Negative and insignificant	Positive and Significant	Negative and insignificant	Moderate
HA	Positive and Significant	Positive and insignificant	Positive and insignificant	Moderate
KA	Negative and insignificant	Positive and Significant	Negative and insignificant	Moderate
MP	Positive and Significant	Negative and insignificant	Positive and insignificant	Moderate
OR	Negative and insignificant	Positive and Significant	Negative and insignificant	Moderate
PU	Positive and Significant	Positive and Significant	Negative and Significant	Moderate
TN	Negative and Significant	Positive and Significant	Negative and insignificant	Moderate
UP	Negative and insignificant	Positive and Significant	Positive and insignificant	Moderate
WB	Negative and insignificant	Positive and Significant	Positive and insignificant	Moderate

Table-3.33: Performance of Wheat State –wise:

States	Overall Trend	Change in the Level after the Break	Change in the Growth after the Break	Performance
BI	Negative and Significant	Positive and Significant	Positive and Significant	Moderate
HA	Negative and insignificant	Positive and Significant	Positive and insignificant	Moderate
MP	Positive and insignificant	Negative and Significant	Positive and insignificant	Bad
PU	Negative and insignificant	Positive and Significant	Positive and insignificant	Moderate
RA	Negative and insignificant	Negative and Significant	Positive and insignificant	Bad
UP	Negative and insignificant	Positive and Significant	Positive and insignificant	Moderate

Table-3.34: Performance of Bajra State –wise:

States	**Overall Trend**	**Change in the Level after the Break**	**Change in the Growth after the Break**	**Performance**
GU	Negative and Significant	Positive and Significant	Positive and insignificant	Moderate
HA	Negative and insignificant	Positive and Significant	Positive and insignificant	Moderate
KA	Positive and Significant	Negative and Significant	Negative and Significant	Moderate
MA	Positive and Significant	Negative and Significant	Negative and Significant	Moderate
RA	Negative and insignificant	Positive and Significant	Positive and insignificant	Moderate
UP	Negative and Significant	Positive and Significant	Positive and insignificant	Moderate

Table-3.35: Performance of Jowar State –wise:

States	**Overall Trend**	**Change in the Level after the Break**	**Change in the Growth after the Break**	**Performance**
AP	Negative and Significant	Positive and Significant	Positive and Significant	Moderate
GU	Negative and Significant	Positive and Significant	Positive and insignificant	Moderate
KA	Positive and Significant	Negative and Significant	Negative and Significant	Moderate
MA	Positive and Significant	Negative and Significant	Negative and Significant	Moderate
RA	Positive and insignificant	Negative and Significant	Positive and Significant	Moderate
TN	Positive and insignificant	Negative and Significant	Positive and insignificant	Bad
UP	Negative and Significant	Positive and Significant	Positive and Significant	Moderate

Table-3.36: Performance of Maize State –wise:

States	Overall Trend	Change in the Level after the Break	Change in the Growth after the Break	Performance
AP	Positive and Significant	Negative and Significant	Positive and insignificant	Moderate
BI	Negative and Significant	Positive and Significant	Positive and Significant	Moderate
GU	Positive and Significant	Negative and insignificant	Negative and Significant	Moderate
HP	Positive and Significant	Negative and Significant	Negative and Significant	Moderate
KA	Negative and Significant	Positive and Significant	Positive and Significant	Moderate
MP	Positive and insignificant	Negative and Significant	Negative and insignificant	Moderate
PU	Negative and insignificant	Positive and insignificant	Positive and insignificant	Bad
RA	Positive and Significant	Negative and Significant	Negative and insignificant	Moderate
UP	Positive and Significant	Negative and Significant	Negative and Significant	Moderate

Table-3.37: Performance of Gram State –wise:

States	Overall Trend	Change in the Level after the Break	Change in the Growth after the Break	Performance
BI	Positive and insignificant	Negative and Significant	Positive and Significant	Moderate
HA	Negative and insignificant	Positive and Significant	Positive and insignificant	Moderate
MA	Positive and Significant	Negative and Significant	Negative and Significant	Moderate
MP	Negative and insignificant	Positive and Significant	Positive and insignificant	Moderate
PU	Negative and insignificant	Positive and Significant	Positive and Significant	Moderate
RA	Positive and insignificant	Positive and Significant	Positive and insignificant	Moderate
UP	Negative and insignificant	Positive and Significant	Positive and insignificant	Moderate

Table-3.38: Performance of Cotton State –wise:

States	Overall Trend	Change in the Level after the Break	Change in the Growth after the Break	Performance
AP	Positive and insignificant	Positive and Significant	Negative and insignificant	Moderate
GU	Negative and insignificant	Positive and Significant	Positive and insignificant	Moderate
HA	Negative and insignificant	Positive and Significant	Negative and Significant	Moderate
KA	Negative and Significant	Positive and Significant	Negative and Significant	Moderate
MP	Positive and insignificant	Positive and insignificant	Negative and insignificant	Bad
MA	Positive and insignificant	Negative and insignificant	Positive and insignificant	Bad
PU	Negative and Significant	Positive and Significant	Positive and Significant	Moderate
RA	Negative and insignificant	Positive and Significant	Positive and Significant	Moderate

Table-3.39: Performance of Groundnut State –wise:

States	Overall Trend	Change in the Level after the Break	Change in the Growth after the Break	Performance
AP	Negative and Significant	Positive and Significant	Positive and insignificant	Moderate
GU	Positive and Significant	Negative and Significant	Negative and Significant	Moderate
KA	Positive and insignificant	Negative and insignificant	Negative and insignificant	Bad
MP	Positive and Significant	Negative and Significant	Negative and Significant	Moderate
TN	Negative and Significant	Positive and Significant	Negative and insignificant	Moderate

Table-3.40: Performance of Rapeseed/Mustard Oil State –wise:

States	Overall Trend	Change in the Level after the Break	Change in the Growth after the Break	Performance
AS	Positive and insignificant	Negative and Significant	Positive and insignificant	Bad
GU	Positive and insignificant	Negative and Significant	Negative and insignificant	Bad
HA	Negative and insignificant	Positive and Significant	Positive and insignificant	Moderate
MP	Negative and Significant	Positive and Significant	Positive and Significant	Moderate
RA	Negative and insignificant	Positive and Significant	Positive and insignificant	Moderate
UP	Negative and insignificant	Positive and Significant	Positive and insignificant	Moderate
WB	Negative and Significant	Positive and Significant	Positive and Significant	Moderate

Table-3.41: Results of Multiple Structural Breaks Analysis in case of Rice

	AP	AS	BI	HA	KA
UDMax statistic	47.24276*	125.0536*	63.22945*	250.8927*	35.45126*
WDMax statistic	75.36502*	171.5747*	86.75142*	295.1527*	69.50872*
SupF(1 vs. 2)	43.79196*	23.51387*	40.29158*	16.33524*	8.149574
SupF(2 vs. 3)	14.92035*	28.13661*	6.884679	15.21037*	
SupF(3 vs. 4)	8.116933	8.599473		22.08581*	
SupF(4 vs. 5)				2.835856	
Estimated break dates	1984	1990	1994	1976	1995
	1991	1998	2004	1987	
	2002	2004		1993	
				2005	
	OR	**PU**	**TN**	**UP**	**WB**
UDMax statistic	26.36988*	2429.206*	75.28616*	117.9542*	82.05325*
WDMax statistic	34.47889*	2857.743*	147.6124*	119.1343*	160.8805*
SupF(1 vs. 2)	23.17205*	159.3957*	18.28168*	51.52672*.	65.84835*
SupF(2 vs. 3)	24.34527*	12.41234	49.78477*	107.6672*	22.73957*
SupF(3 vs. 4)	14.87488*		9.004365	1.900478	10.09125
SupF(4 vs. 5)	13.50913				
Estimated break dates	1977	1977	1977	1978	1982
	1983	1983	1984	1988	1987
	1996		2002	2002	2001
	2003				

*** Significant at the 0.05 level.**

Bai-Perron (Econometric Journal, 2003) critical values.

Table-3.42: Results of Multiple Structural Breaks Analysis in case of Wheat

	BI	HA	MP	PU	RA	UP
UDMax statistic	112.8554*	362.8244*	146.3379*	848.4826*	237.3191*	274.214*
WDMax statistic	247.6468*	796.1723*	303.3199*	1861.888*	520.7667*	601.7279*
SupF(1 vs. 2)	22.0002*	23.98422*	46.13951*	27.51196*	34.68392*	29.45996*
SupF(2 vs. 3)	9.913788	23.32568*	99.72367*	23.122*	23.9026*	38.30587*
SupF(3 vs. 4)		21.67169*	1.976413	34.47682*	8.958883	22.89412*
SupF(4 vs. 5)		4.6309		3.754129		12.1804
	1987	1978	1982	1977	1977	1976
	1993	1985	1993	1984	1990	1982
		1991		1989	1996	1988
Estimated break dates		1998		1999		1996
*** Significant at the 0.05 level.**						
Bai-Perron (Econometric Journal, 2003) critical values.						

Table-3.43: Results of Multiple Structural Breaks Analysis in case of Bajra

	GU	HA	KA	MA	RA	UP
UDMax statistic		78.46587*		52.34845*	63.98836*	53.41472*
WDMax statistic		101.7481*		114.872*	63.98836*	69.64917*
SupF(1 vs. 2)		12.72837*		14.87116*	11.18491*	20.91623*
SupF(2 vs. 3)		3.756412		2.282992	3.527285	1.583145
SupF(3 vs. 4)						
SupF(4 vs. 5)	NA		NA			
		1994		1987	1990	1992
		2006		2001	2003	2004
Estimated break dates						
*** Significant at the 0.05 level.**						
Bai-Perron (Econometric Journal, 2003) critical values.						

Table-3.44: Results of Multiple Structural Breaks Analysis in case of Gram

	BI	HA	MP	MA	RA	UP
UDMax statistic	138.0257*	126.8883*	145.4344*	154.5388*	22.92119*	115.9312*
WDMax statistic	138.0257*	211.1111*	177.0703*	266.3642*	47.3946*	168.069*
SupF(1 vs. 2)	23.55571*	29.59919*	107.7312*	77.69229*	24.78312*	122.4577*
SupF(2 vs. 3)	0.785671	3.88731	7.571794	8.413394	0.929628	21.08821*
SupF(3 vs. 4)						1.424338
SupF(4 vs. 5)						
	1995	1981	1981	1989	1999	1987
	2001	1999	1993	2005	2006	1995
						2006
Estimated break dates						
*** Significant at the 0.05 level.**						
Bai-Perron (Econometric Journal, 2003) critical values.						

Table-3.45: Results of Multiple Structural Breaks Analysis in case of Jowar

	AP	GU	KA	MA	RA	TN	UP
UDMax statistic	169.2013*	109.591*	8.620705			163.2376*	121.6691*
WDMax statistic	339.4489*	188.435*	8.620705			234.9964*	210.3239*
SupF(1 vs. 2)	40.07835*	9.282778				64.36633*	54.5455*
SupF(2 vs. 3)	30.79875*					2.076473	2.804721
SupF(3 vs. 4)	2.61425						
SupF(4 vs. 5)			NA	NA	NA		
	1986	1986				1992	1997
	1994					2001	2006
Estimated break dates	2006						
*** Significant at the 0.05 level.**							
Bai-Perron (Econometric Journal, 2003) critical values.							

Table -3.46: Results of Multiple Structural Breaks Analysis in case of Maize

	AP	**BI**	**GU**	**HP**	**KA**
UDMax statistic	172.0828*	194.4399*	53.8119*	69.9861*	470.8096*
WDMax statistic	271.8668*	350.8722*	75.1297*	121.4788*	1033.1320*
SupF(1 vs. 2)	26.6460*	15.3056*	26.7536*	44.7224*	26.3339*
SupF(2 vs. 3)	15.1775*	8.1819	11.6364*	14.9821*	16.3466*
SupF(3 vs. 4)	13.1933*		1.1422	7.3771	5.3338
SupF(4 vs. 5)	0.0000				
	1980	1991	1989	1983	1989
	1990	1998	1996	1998	1996
	1998		2002	2006	2002
Estimated break dates	2006				

	MP	**PU**	**RA**	**UP**
UDMax statistic	86.1347*	100.2042*	55.2818*	42.5659*
WDMax statistic	184.1286*	219.8854*	74.5751*	81.1551*
SupF(1 vs. 2)	14.5575*	27.2779*	31.2545*	3.3345
SupF(2 vs. 3)	4.0923	14.3921*	6.6536	
SupF(3 vs. 4)		12.6410*		
SupF(4 vs. 5)		7.6146		
	1981	1976	1989	1984
	1992	1982	2006	
		1988		
Estimated break dates		1999		

*** Significant at the 0.05 level.**

Bai-Perron (Econometric Journal, 2003) critical values.

Table -3.47: Results of Multiple Structural Breaks Analysis in case of Cotton

	AP	GU	HA	KA
UDMax statistic	114.6967*	73.01903*	177.3607*	18.11627*
WDMax statistic	191.4605*	97.41117*	334.7769*	26.08013*
SupF(1 vs. 2)	20.63115*	3.969035	49.53746*	5.021589
SupF(2 vs. 3)	23.13381*		35.44931*	
SupF(3 vs. 4)	2.897302		9.967719	
SupF(4 vs. 5)				
Estimated break dates	1979	2003	1978	2005
	1990		1989	
	2006		2004	
	MA	**MP**	**PU**	**RA**
UDMax statistic	194.8218*	NA	88.53323*	95.26789*
WDMax statistic	280.465*		152.2275*	163.8073*
SupF(1 vs. 2)	66.17906*		4.35792	7.893457
SupF(2 vs. 3)	60.56545*			
SupF(3 vs. 4)	7.807706			
SupF(4 vs. 5)				
Estimated break dates	1977		2004	1988
	1993			
	2006			
*** Significant at the 0.05 level.**				
Bai-Perron (Econometric Journal, 2003) critical values.				

Table -3.48: Results of Multiple Structural Breaks Analysis in case of Groundnut

	AP	GU	KA	MP	TN
UDMax statistic	NA	23.62172*	NA	NA	NA
WDMax statistic		39.83377*			
SupF(1 vs. 2)		2.580419			
SupF(2 vs. 3)					
SupF(3 vs. 4)					
SupF(4 vs. 5)					
Estimated break dates		2003			
*** Significant at the 0.05 level.**					
Bai-Perron (Econometric Journal, 2003) critical values.					

Table- 3.49: Results of Multiple Structural Breaks Analysis in case of Rapeseed/Mustard Oil

	AS	GU	HA	MP
UDMax statistic	119.5747*	215.2135*	392.4145*	106.8401*
WDMax statistic	176.6138*	429.121*	737.103*	163.3756*
SupF(1 vs. 2)	4.957182	62.3609*	31.27176*	33.63816*
SupF(2 vs. 3)		16.28174*	10.99172	22.33001*
SupF(3 vs. 4)		8.486486		0.814996
SupF(4 vs. 5)				
Estimated break dates	1980	1976	1980	1980
		1982	1988	1989
		1989		2003
	RA	**UP**	**WB**	
UDMax statistic	539.9132*	20.18047*	472.3176*	
WDMax statistic	777.2576*	32.74588*	794.9673*	
SupF(1 vs. 2)	75.74381*	14.16038*	18.07206*	
SupF(2 vs. 3)	33.9834*	25.32614*	17.25195*	
SupF(3 vs. 4)	4.328398	2.894729	1.532585	
SupF(4 vs. 5)				
Estimated break dates	1981	1982	1978	
	1988	1990	1984	
	2002	1997	2000	
*** Significant at the 0.05 level.**				
Bai-Perron (Econometric Journal, 2003) critical values.				

Table-3.50: Estimated Results of Simultaneous Equation Model Not by Taking Input Growth as Explanatory Variable: The Case of Growth of Output Equation in case of Rice

Variable	Coefficient	t-Statistic	Prob.
C	826.56**	2.43	0.0154
RF	0.165**	2.420	0.0159
HYV	0.501**	2.431	0.0154
AL	0.145**	2.402	0.0164
RL	0.328**	2.413	0.0162
GI	0.236*	4.296	0
E	0.436*	3.194	0.0015
G	-0.609*	-6.532	0
G*G	0.0754*	4.682	0
RL*E	0.0018***	1.787	0.0746
RF*HYV	-0.3147*	-3.921	0.0001
Adjusted R-squared	0.916582		
F-statistic	254.2682		
Prob(F-statistic)	0		

***significant at 1%, **significant at 5%, ***significant at 10%**

Table-3.51: Estimated Results of Simultaneous Equation Model Not by Taking Input Growth as Explanatory Variable: The Case of HYV Equation in case of Rice

Variable	Coefficient	t-Statistic	Prob.
C	-23.5474*	-15.2349	0
GR	4.133844*	12.78951	0
GR*GR	-0.2427*	-14.2727	0
GI	0.024484**	2.178313	0.0299
AL	0.045325*	2.835709	0.0048
RL	1.570272*	21.83247	0
E	0.013912**	2.495997	0.0129
E*AL	0.003504*	4.316668	0
DN	0.3333*	12.90841	0
DS	0.053753*	4.750023	0
Adjusted R-squared	0.944176		
F-statistic	459.6513		
Prob(F-statistic)	0		

***significant at 1%, **significant at 5%, ***significant at 10%**

Table-3.52: Marginal Effects of the Explanatory Variables from the Simultaneous Equation Model Not by Taking Input Growth as Explanatory Variable: The Case of Growth of Output Equation in case of Rice

RF	0.166
HYV	0.501
RL	0.328
E	0.432
G	-0.707

Table-3.53: Wald Statistics of the Simultaneous Equation Model Not by Taking Input Growth as Explanatory Variable: The Case of Growth of Output Equation in case of Rice

	RF	**HYV**	**RL**	**E**	**G**
F-statistic	11.326*	12.577*	4.856*	12.786*	24.324*
Chi-square	22.65*	25.15*	9.713*	25.569*	48.648*

***significant at 1%, **significant at 5%, ***significant at 10%**

Table-3.54: Marginal Effects of the Explanatory Variables from the Simultaneous Equation Model Not by Taking Input Growth as Explanatory Variable: The Case of HYV Equation in case of Rice

GR	0.0438
AL	0.0506
E	0.0137

Table-3.55: Wald Statistics of the Simultaneous Equation Model Not by Taking Input Growth as Explanatory Variable: The Case of HYV Equation in case of Rice

	GR
F-statistic	135.680*
Chi-square	271.360*

***significant at 1%, **significant at 5%, ***significant at 10%**

Table-3.56: Estimated Results of Simultaneous Equation Model Not by Taking Input Growth as Explanatory Variable: The Case of Growth of Output Equation in case of Wheat

Variable	Coefficient	t-Statistic	Prob.
C	30.60471*	9.88273	0.00000
RF	1.10195**	2.17289	0.03080
RF*RF	-0.07197***	-1.87486	0.06200
HYV	0.14201*	6.75739	0.00000
GI	0.63275*	5.28551	0.00000
AL	0.25954*	4.30599	0.00000
E	0.04682*	3.80044	0.00020
RL	0.00762*	6.82352	0.00000
G	-0.15746*	-4.06480	0.00010
G*G	0.01875**	2.16687	0.03120
DN	1.21697*	11.60741	0.00000
DE	0.32510*	4.25304	0.00000
DM	0.25536*	4.10913	0.00010
Adjusted R-squared	0.94129		
F-statistic	336.35400		
Prob(F-statistic)	0.00000		

***significant at 1%, **significant at 5%, ***significant at 10%**

Table-3.57: Estimated Results of Simultaneous Equation Model Not by Taking Input Growth as Explanatory Variable: The Case of HYV Equation in case of Wheat

Variable	Coefficient	t-Statistic	Prob.
C	-4.53916	-4.42301	0
GR	0.75994	3.270338	0.0012
GR*GR	-0.04274	-3.59165	0.0004
PI	0.129843	2.329847	0.0206
AL	0.02243	2.623463	0.0093
RL	0.542801	9.412507	0
E	0.014544	2.282094	0.0234
AL*E	0.002915	2.586666	0.0103
Adjusted R-squared	0.964011		
F-statistic	561.2777		
Prob(F-statistic)	0		

***significant at 1%, **significant at 5%, ***significant at 10%**

Table-3.58: Marginal Effects of the Explanatory Variables from the Simultaneous Equation Model Not by Taking Input Growth as Explanatory Variable: The Case of Growth of Output Equation in case of Wheat

RF	0.13609
HYV	0.14201
GI	0.63275
AL	0.25954
E	0.04682
RL	0.00762
GI	-0.19628

Table-3.59: Wald Statistics of the Simultaneous Equation Model Not by Taking Input Growth as Explanatory Variable: The Case of Growth of Output Equation in case of Wheat

	RF	**G**
F-statistic	5.33593*	18.12600*
Chi-square	10.67185*	36.25199*

***significant at 1%, **significant at 5%, ***significant at 10%**

Table-3.60: Marginal Effects of the Explanatory Variables from the Simultaneous Equation Model Not by Taking Input Growth as Explanatory Variable: The Case of HYV Equation in case of Wheat

GR	0.011847
PI	0.129843
AL	0.027073
RL	0.542801
E	0.002438

Table-3.61: Wald Statistics of the Simultaneous Equation Model Not by Taking Input Growth as Explanatory Variable: The Case of HYV Equation in case of Wheat

	GR	**AL**
F-statistic	15.93945	4.263627
Chi-square	31.8789	8.527253

***significant at 1%, **significant at 5%, ***significant at 10%**

Table-3.62: Estimated Results of Simultaneous Equation Model: The Case of Growth of Output Equation in case of Bajra

Variable	Coefficient	t-Statistic	Prob.
C	21.58990*	3.45191	0.00070
RF	3.77057**	2.20089	0.02870
RF*RF	-0.23925***	-2.01405	0.04510
HYV	1.79662**	2.31553	0.02140
GI	1.64409*	2.39609	0.00212
AL	0.15181*	3.04154	0.00260
E	0.01229*	5.53142	0.00000
G	-0.28534**	-2.31386	0.02150
G*G	0.06039*	3.14287	0.00190
RF*GI	-0.18462	-1.62596	0.10530
RF*HYV	-0.17198*	-2.35845	0.01920
Adjusted R-squared	0.73823		
F-statistic	48.19021		
Prob(F-statistic)	0.00000		

***significant at 1%, **significant at 5%, ***significant at 10%**

Table-3.63: Estimated Results of Simultaneous Equation Model: The Case of HYV Equation in case of Bajra

Variable	Coefficient	t-Statistic	Prob.
C	-421.83150**	-2.49075	0.01340
GR	7.77362**	2.52848	0.01210
GR*GR	-0.56602**	-2.58672	0.01030
AL	0.20204*	6.96735	0.00000
RL	0.03744*	15.67914	0.00000
E	0.13050*	9.97325	0.00000
DW	-0.18310*	-6.35137	0.00000
DN	0.77144*	26.10371	0.00000
Adjusted R-squared	0.90465		
F-statistic	341.18630		
Prob(F-statistic)	0.00000		

***significant at 1%, **significant at 5%, ***significant at 10%**

Table-3.64: Marginal Effects of the Explanatory Variables from the Simultaneous Equation Model: The Case of Growth of Output Equation in case of Bajra

RF	0.91600
HYV	0.63716
GI	0.39942
AL	0.15181
E	0.01229
GI	-0.41597

Table-3.65: Wald Statistics of the Simultaneous Equation Model: The Case of Growth of Output Equation in case of Bajra

	RF	**HYV**	**GI**	**G**
F-statistic	2.34281***	2.78367***	2.37213***	7.55323*
Chi-square	9.37125***	5.56734***	4.74426***	15.10646*

***significant at 1%, **significant at 5%, ***significant at 10%**

Table-3.66: Marginal Effects of the Explanatory Variables from the Simultaneous Equation Model: The Case of HYV Equation in case of Bajra

GR	0.31368
AL	0.20204
RL	0.03744
E	0.13050

Table-3.67: Wald Statistics of the Simultaneous Equation Model: The Case of HYV Equation in case of Bajra

	GR
F-statistic	30.31427*
Chi-square	60.62855*

***significant at 1%, **significant at 5%, ***significant at 10%**

Table-3.68: Estimated Results of Simultaneous Equation Model: The Case of Growth of Output Equation in case of Gram

Variable	Coefficient	t-Statistic	Prob.
C	-1.33921	-0.22775	0.82
RF	2.073023*	4.174577	0
RF*RF	-0.14453*	-5.07106	0
HYV	0.550465*	5.443058	0
HYV*HYV	-0.21929*	-4.0148	0.0001
GI	0.350814**	2.427664	0.0159
AL	0.035364*	6.459	0
E	0.09017*	5.027168	0
G	-0.00566*	-3.6642	0
G*G	0.003881**	2.158922	0.0167
Adjusted R-squared	0.910156		
F-statistic	182.6231		
Prob(F-statistic)	0		

***significant at 1%, **significant at 5%, ***significant at 10%**

Table-3.69: Estimated Results of Simultaneous Equation Model: The Case of HYV Equation in case of Gram

Variable	Coefficient	t-Statistic	Prob.
C	-62.1737*	-5.17436	0
GR	6.86339*	4.771533	0
GR*GR	-0.52155*	-4.72761	0
GI	0.14878*	2.856555	0.0047
AL	0.06289**	2.243316	0.0258
E	0.028787*	2.675952	0.008
RL	0.51955*	14.97343	0
DM	0.414136*	6.310347	0
DN	0.450859*	15.31741	0
DW	0.713752*	10.10727	0
Adjusted R-squared	0.9603		
F-statistic	552.9504		
Prob(F-statistic)	0		

***significant at 1%, **significant at 5%, ***significant at 10%**

Table-3.70: Marginal Effects of the Explanatory Variables from the Simultaneous Equation Model: The Case of Growth of Output Equation in case of Gram

RF	0.127882
HYV	0.937079
GI	0.350814
AL	0.035364
E	0.09017
GI	-0.01248

Table-3.71: Wald Statistics of the Simultaneous Equation Model: The Case of Growth of Output Equation in case of Gram

	RF	HYV	G
F-statistic	7.137491*	25.90537*	11.13233*
Chi-square	24.27498*	51.81074*	32.26465*

***significant at 1%, **significant at 5%, ***significant at 10%**

Table-3.72: Marginal Effects of the Explanatory Variables from the Simultaneous Equation Model: The Case of HYV Equation in case of Gram

GR	0.457576
GI	0.14878
AL	0.06289
E	0.028787
RL	0.51955

Table-3.73: Wald Statistics of the Simultaneous Equation Model: The Case of HYV Equation in case of Gram

	GR
F-statistic	11.82231*
Chi-square	23.64462*

***significant at 1%, **significant at 5%, ***significant at 10%**

Table-3.74: Estimated Results of Simultaneous Equation Model Not by Taking Input Growth as Explanatory Variable: The Case of Growth of Output Equation in case of Jowar

Variable	Coefficient	t-Statistic	Prob.
C	7.917828*	17.47819	0
RF	0.017882*	3.28507	0.0072
HYV	0.487224*	5.240551	0
HYV*HYV	-0.09814*	-2.62057	0.0093
GI	0.094813*	10.93482	0
AL	0.085008*	4.981074	0
E	0.068859*	4.638743	0
G	-0.20351*	-4.58963	0
G*G	0.062079*	2.817891	0.0052
Adjusted R-squared	0.91039		
F-statistic	213.6227		
Prob(F-statistic)	0		

***significant at 1%, **significant at 5%, ***significant at 10%**

Table-3.75: Estimated Results of Simultaneous Equation Model Not by Taking Input Growth as Explanatory Variable: The Case of HYV Equation in case of Jowar

Variable	Coefficient	t-Statistic	Prob.
C	22.19598*	4.867413	0
GR	0.971182*	5.850366	0
GR*GR	-0.06643*	-5.594	0
GI	0.153409*	7.311702	0
AL	0.103083*	6.334875	0
RL	0.078094*	17.22933	0
DW	-0.73453*	-17.0428	0
DS	-0.58555*	-13.1896	0
Adjusted R-squared	0.924878		
F-statistic	328.9384		
Prob(F-statistic)	0		

***significant at 1%, **significant at 5%, ***significant at 10%**

Table-3.76: Marginal Effects of the Explanatory Variables from the Simultaneous Equation Model Not by Taking Input Growth as Explanatory Variable: The Case of Growth of Output Equation in case of Jowar

RF	0.017882
HYV	0.644232
GI	0.094813
AL	0.085008
E	0.068859
G	-0.31559

Table-3.77: Wald Statistics of the Simultaneous Equation Model Not by Taking Input Growth as Explanatory Variable: The Case of Growth of Output Equation in case of Jowar

	HYV	G
F-statistic	15.03413*	6.942036*
Chi-square	30.06825*	13.88407*

***significant at 1%, **significant at 5%, ***significant at 10%**

Table-3.78: Marginal Effects of the Explanatory Variables from the Simultaneous Equation Model Not by Taking Input Growth as Explanatory Variable: The Case of HYV Equation in case of Jowar

GR	0.109677
GI	0.153409
AL	0.103083
RL	0.078094

Table-3.79: Wald Statistics of the Simultaneous Equation Model Not by Taking Input Growth as Explanatory Variable: The Case of HYV Equation in case of Jowar

	GR
F-statistic	83.14141*
Chi-square	166.2828*

***significant at 1%, **significant at 5%, ***significant at 10%**

Table-3.80: Estimated Results of Simultaneous Equation Model: The Case of Growth of Output Equation in case of Maize

Variable	Coefficient	t-Statistic	Prob.
C	-13.2456**	-2.57523	0.0104
RF	0.084409*	3.518799	0.0056
HYV	0.86633*	2.960401	0.0033
PI	0.21343*	3.617812	0.0047
AL	0.079609***	1.872962	0.0619
E	0.099907*	2.918574	0.0037
RL	0.268487*	3.899224	0.0001
G	-0.02155**	-2.45623	0.0145
G*G	0.009218*	5.671622	0
Adjusted R-squared	0.86954		
F-statistic	158.0479		
Prob(F-statistic)	0		

***significant at 1%, **significant at 5%, ***significant at 10%**

Table-3.81: Estimated Results of Simultaneous Equation Model: The Case of HYV Equation in case of Maize

Variable	Coefficient	t-Statistic	Prob.
C	-25.3979*	-23.2489	0
GR	2.901689*	16.98795	0
GR*GR	-0.18412*	-17.914	0
GI	0.127052*	5.686728	0
E	0.009613*	4.106774	0
RL	0.002677*	14.02091	0
DE	-0.04828***	-1.7881	0.0746
DW	-0.6303*	-16.7937	0
DM	-0.09964**	-2.51788	0.0122
DS	-0.34711	-15.2827	0
Adjusted R-squared	0.951081		
F-statistic	564.8127		
Prob(F-statistic)	0		

***significant at 1%, **significant at 5%, ***significant at 10%**

Table-3.82: Marginal Effects of the Explanatory Variables from the Simultaneous Equation Model: The Case of Growth of Output Equation in case of Maize

RF	0.084409
HYV	0.86633
PI	0.21343
AL	0.079609
E	0.099907
RL	0.268487
G	-0.04162

Table-3.83: Wald Statistics of the Simultaneous Equation Model: The Case of Growth of Output Equation in case of Maize

	G
F-statistic	56.17378*
Chi-square	112.3476*

***significant at 1%, **significant at 5%, ***significant at 10%**

Table-3.84: Marginal Effects of the Explanatory Variables from the Simultaneous Equation Model: The Case of HYV Equation in case of Maize

GR	0.448016
GI	0.127052
E	0.009613
RL	0.002677

Table-3.85: Wald Statistics of the Simultaneous Equation Model: The Case of HYV Equation in case of Maize

	GR
F-statistic	199.8432*
Chi-square	399.6863*

***significant at 1%, **significant at 5%, ***significant at 10%**

Table-3.86: Estimated Results of Simultaneous Equation Model: The Case of Growth of Output Equation in case of Cotton

Variable	Coefficient	t-Statistic	Prob.
C	-4.05539	-0.79703	0.426
RF	3.436668**	2.268374	0.024
RF*RF	-0.24045**	-2.13383	0.0336
HYV	0.482939*	6.624914	0
HYV*HYV	-0.15532*	-4.05961	0.0001
GI	0.649751*	2.598172	0.0098
AL	0.193362**	2.321526	0.0209
E	0.065547*	2.630478	0.0089
G	-0.02324*	-5.24795	0
G*G	0.031594***	1.687299	0.0925
GI*AL	0.15167*	2.932996	0.0036
Adjusted R-squared	0.901894		
F-statistic	182.1563		
Prob(F-statistic)	0		

***significant at 1%, **significant at 5%, ***significant at 10%**

Table-3.87: Estimated Results of Simultaneous Equation Model: The Case of HYV Equation in case of Cotton

Variable	Coefficient	t-Statistic	Prob.
C	-16.2187*	-17.476	0
GR	3.1969*	13.85241	0
GR*GR	-0.2269*	-14.556	0
GI	0.079413*	3.052349	0.0025
AL	0.051534**	1.922343	0.0554
E	0.012231*	4.413511	0
RL	0.027739*	19.70711	0
DW	0.538147*	19.00642	0
DN	0.239632*	6.423261	0
DS	0.091537**	2.543811	0.0114
Adjusted R-squared	0.911351		
F-statistic	265.9182		
Prob(F-statistic)	0		

***significant at 1%, **significant at 5%, ***significant at 10%**

Table-3.88: Marginal Effects of the Explanatory Variables from the Simultaneous Equation Model: The Case of Growth of Output Equation in case of Cotton

RF	0.206489
HYV	0.713412
GI	0.038148
AL	0.020561
E	0.065547
G	-0.10574

Table-3.89: Wald Statistics of the Simultaneous Equation Model: The Case of Growth of Output Equation in case of Cotton

	RF	**HYV**	**GI**	**AL**
F-statistic	6.630344*	33.75592*	4.318889**	4.318688**
Chi-square	13.26069*	67.51185*	8.637777**	8.637376**

***significant at 1%, **significant at 5%, ***significant at 10%**

Table-3.90: Marginal Effects of the Explanatory Variables from the Simultaneous Equation Model: The Case of HYV Equation in case of Cotton

GR	0.06464
GI	0.079413
AL	0.051534
E	0.012231
RL	0.027739

Table-3.91: Wald Statistics of the Simultaneous Equation Model: The Case of HYV Equation in case of Cotton

	GR
F-statistic	120.0105*
Chi-square	240.0211*

***significant at 1%, **significant at 5%, ***significant at 10%**

Table-3.92: Estimated Results of Simultaneous Equation Model: The Case of Growth of Output Equation in case of Groundnut

Variable	Coefficient	t-Statistic	Prob.
C	12.6256*	4.089749	0.0001
RF	1.729194**	1.911294	0.0574
RF*RF	-0.12077**	-1.83196	0.0685
HYV	0.435812*	2.771758	0.0061
HYV*HYV	-0.17833***	-1.65516	0.0995
PI	0.080116*	4.267565	0
E	0.156833*	4.514909	0
G	-0.07433	-5.49111	0
G*G	0.112784***	1.928147	0.0553
AL*E	0.028522*	3.730265	0.0003
Adjusted R-squared	0.897798		
F-statistic	142.2277		
Prob(F-statistic)	0		

***significant at 1%, **significant at 5%, ***significant at 10%**

Table-3.93: Estimated Results of Simultaneous Equation Model: The Case of HYV Equation in case of Groundnut

Variable	Coefficient	t-Statistic	Prob.
C	233.0498*	3.406512	0.0008
GR	7.7143*	3.426829	0.0007
GR*GR	-0.55871*	-3.35942	0.0009
GI	0.12254*	3.31153	0.0011
AL	0.026789*	6.440737	0
E	0.041818*	4.500627	0
RL	0.001848*	15.30145	0
Adjusted R-squared	0.910035		
F-statistic	212.4138		
Prob(F-statistic)	0		

***significant at 1%, **significant at 5%, ***significant at 10%**

Table-3.94: Marginal Effects of the Explanatory Variables from the Simultaneous Equation Model: The Case of Growth of Output Equation in case of Groundnut

RF	0.050855
HYV	0.65618
PI	0.080116
E	0.034162
AL	0.043833
G	-0.26032

Table-3.95: Wald Statistics of the Simultaneous Equation Model: The Case of Growth of Output Equation in case of Groundnut

	RF	**HYV**	**E**	**G**
F-statistic	9.27335*	3.985746**	10.8321*	3.493505**
Chi-square	24.5467*	7.971492**	21.66421*	6.98701**

***significant at 1%, **significant at 5%, ***significant at 10%**

Table-3.96: Marginal Effects of the Explanatory Variables from the Simultaneous Equation Model: The Case of HYV Equation in case of Groundnut

GR	0.208563
GI	0.12254
AL	0.026789
E	0.041818
RL	0.001848

Table-3.97: Wald Statistics of the Simultaneous Equation Model: The Case of HYV Equation in case of Groundnut

	GR
F-statistic	61.94449*
Chi-square	123.889*

***significant at 1%, **significant at 5%, ***significant at 10%**

Table-3.98: Estimated Results of Simultaneous Equation Model: The Case of Growth of Output Equation in case of Rapeseed/Mustard Oil

Variable	Coefficient	t-Statistic	Prob.
C	-310.236*	-5.35662	0
RF	0.066198*	5.734011	0
HYV	0.687731*	5.442236	0
HYV*HYV	-0.0029*	-5.40263	0
PI	0.296189*	3.238134	0.0013
AL	0.019322*	5.566765	0
E	0.087182*	4.997716	0
RL	0.00889*	5.477466	0
G	-0.00368*	-5.9219	0
G*G	0.123528*	4.635437	0
Adjusted R-squared	0.929899		
F-statistic	260.1117		
Prob(F-statistic)	0		

***significant at 1%, **significant at 5%, ***significant at 10%**

Table-3.99: Estimated Results of Simultaneous Equation Model: The Case of HYV Equation in case of Rapeseed/Mustard Oil

Variable	Coefficient	t-Statistic	Prob.
C	-4.19827*	-6.21469	0
GR	0.224605**	1.883762	0.0606
GR*GR	-0.01009***	-1.6688	0.0963
GI	0.023473**	2.020195	0.0443
AL	0.155964*	3.485019	0.0006
RL	0.086916*	7.08328	0
DN	0.386939*	5.10903	0
DE	0.403713*	4.807767	0
DW	0.674578*	12.23741	0
Adjusted R-squared	0.931463		
F-statistic	363.0085		
Prob(F-statistic)	0		

***significant at 1%, **significant at 5%, ***significant at 10%**

Table-3.100: Marginal Effects of the Explanatory Variables from the Simultaneous Equation Model: The Case of Growth of Output Equation in case of Rapeseed/Mustard Oil

RF	0.066198
HYV	0.692579
PI	0.296189
AL	0.019322
E	0.087182
RL	0.00889
G	-0.22735

Table-3.101: Wald Statistics of the Simultaneous Equation Model: The Case of Growth of Output Equation in case of Rapeseed/Mustard Oil

	HYV	**G**
F-statistic	23.81888*	38.8408*
Chi-square	47.63776*	77.6816*

***significant at 1%, **significant at 5%, ***significant at 10%**

Table-3.102: Marginal Effects of the Explanatory Variables from the Simultaneous Equation Model: The Case of HYV Equation in case of Rapeseed/Mustard Oil

GR	0.108427
GI	0.023473
AL	0.155964
RL	0.086916

Table-3.103: Wald Statistics of the Simultaneous Equation Model: The Case of HYV Equation in case of Rapeseed/Mustard Oil

	GR
F-statistic	11.75301*
Chi-square	23.50602*

***significant at 1%, **significant at 5%, ***significant at 10%**

Table-3.104: Reasons for Benchmark Region for Taking Regional Dummy

Crops	Benchmark Region	Reasons
Rice	Middle Region	Share is Minimum
Wheat	Western Region	Share is Minimum
Bajra	Southern Region	Share is Minimum
Jowar	Northern region	Share is Minimum
Maize	Northern region	Share is Maximum
Gram	Eastern Region	Share is Minimum
Cotton	Middle Region	Share is Minimum
Groundnut	Nil	
Rapeseed/Mustard Oil	Middle Region	Share is Minimum

Table-3.105: Estimated Results of Simultaneous Equation Model by Taking Input Growth as Explanatory Variable: The Case of Growth of Output Equation in case of Rice

Variable	Coefficient	t-Statistic	Prob.
C	100.8164*	8.710946	0
RF	0.846546*	4.919777	0
RF*RF	-0.06052*	-4.22116	0
HYV	0.307726*	5.421434	0
HYV*HYV	-0.26763*	-3.65336	0.0003
AL	0.13394*	4.026454	0.0001
RL	0.532253*	5.070573	0
GI	0.268438*	3.196337	0.0014
E	0.054779*	4.230039	0
G	-0.18542*	-6.15815	0
G*G	0.213232*	9.124567	0
F	0.083249*	5.894569	0
M	0.050559**	2.389593	0.0171
L	27.45589*	8.708108	0
L*L	-1.99062*	-8.64285	0
Adjusted R-squared	0.876582		
F-statistic	364.2682		
Prob(F-statistic)	0		

***significant at 1%, **significant at 5%, ***significant at 10%**

Table-3.106: Estimated Results of Simultaneous Equation Model by Taking Input Growth as Explanatory Variable: The Case of HYV Equation in case of Rice

Variable	Coefficient	t-Statistic	Prob.
C	-5.03526*	-4.18913	0
GR	0.695737**	2.41391	0.016
GR*GR	-0.02978***	-1.70937	0.0877
GI	0.391461*	10.62511	0
AL	0.216753*	17.35273	0
E	0.018475*	2.901681	0.0038
RL	0.153717*	3.053515	0.0023
F	0.150626*	13.94169	0
DS	-0.01939	-0.52312	0.601
DN	0.120096*	2.824924	0.0048
Adjusted R-squared	0.90176		
F-statistic	289.6513		
Prob(F-statistic)	0		

***significant at 1%, **significant at 5%, ***significant at 10%**

Table-3.107: Marginal Effects of the Explanatory Variables from the Simultaneous Equation Model by Taking Input Growth as Explanatory Variable: The Case of Growth of Output Equation in case of Rice

RF	0.087212
HYV	0.648407
AL	0.13394
RL	0.532253
GI	0.268438
E	0.054779
G	-0.46353
F	0.083249
M	0.050559
L	0.047801

Table-3.108: Wald Statistics of the Simultaneous Equation Model by Taking Input Growth as Explanatory Variable: The Case of Growth of Output Equation in case of Rice

	RF	HYV	G	L
Chi-square	19.52806*	212.7891*	116.0203*	77.68348*

***significant at 1%, **significant at 5%, ***significant at 10%**

Table-3.109: Marginal Effects of the Explanatory Variables from the Simultaneous Equation Model by Taking Input Growth as Explanatory Variable: The Case of HYV Equation in case of Rice

GR	0.193114
GI	0.391461
AL	0.216753
E	0.018475
RL	0.153717
F	0.150626

Table-3.110: Wald Statistics of the Simultaneous Equation Model by Taking Input Growth as Explanatory Variable: The Case of HYV Equation in case of Rice

	GR
Chi-square	247.360*

***significant at 1%, **significant at 5%**

Table-3.111: Estimated Results of Simultaneous Equation Model by Taking Input Growth as Explanatory Variable: The Case of Growth of Output Equation in case of Wheat

Variable	**Coefficient**	**t-Statistic**	**Prob.**
C	-16.1103**	-2.15386	0.0318
RF	0.590924*	7.002216	0
RF*RF	-0.0244*	-4.73912	0
HYV	0.206076*	10.75553	0
HYV*HYV	-0.15804*	-3.04428	0.0025
AL	0.319294*	7.335033	0
RL	0.442333**	2.548574	0.0111
GI	0.343575**	2.129668	0.0337
E	0.133103*	5.920162	0
G	-0.13802*	-11.4861	0
G*G	0.009427*	7.376369	0
F	0.357676*	5.638465	0
M	0.023759	1.540591	0.1241
L	8.308853*	5.10453	0
L*L	-0.64035*	-4.93915	0
Adjusted R-squared	0.923485		
F-statistic	264.1678		
Prob(F-statistic)	0		

***significant at 1%, **significant at 5%, ***significant at 10%**

Table-3.112: Estimated Results of Simultaneous Equation Model by Taking Input Growth as Explanatory Variable: The Case of HYV Equation in case of Wheat

Variable	Coefficient	t-Statistic	Prob.
C	6.298713**	2.443045	0.0149
GR	2.015805*	3.454548	0.0006
GR*GR	-0.1103*	-3.32223	0.001
PI	0.412507*	11.97999	0
AL	0.210933*	8.674302	0
E	0.107649*	8.661812	0
RL	0.219681*	5.410862	0
F	0.166799*	4.01403	0.0001
DN	0.862492*	9.980005	0
DE	-0.44937*	-7.98339	0
Adjusted R-squared	0.94873		
F-statistic	342.2578		
Prob(F-statistic)	0		

***significant at 1%, **significant at 5%, ***significant at 10%**

Table-3.113: Marginal Effects of the Explanatory Variables from the Simultaneous Equation Model by Taking Input Growth as Explanatory Variable: The Case of Growth of Output Equation in case of Wheat

RF	0.263775
HYV	0.437164
AL	0.319294
RL	0.442333
GI	0.343575
E	0.133103
G	-0.15772
F	0.357676
M	0.306948
L	0.263775

Table-3.114: Wald Statistics of the Simultaneous Equation Model by Taking Input Growth as Explanatory Variable: The Case of Growth of Output Equation in case of Wheat

	RF	HYV	G	L
Chi-square	4.63912***	56.30542*	5.117918***	107.5255*

***significant at 1%, **significant at 5%, ***significant at 10%**

Table-3.115: Marginal Effects of the Explanatory Variables from the Simultaneous Equation Model by Taking Input Growth as Explanatory Variable: The Case of HYV Equation in case of Wheat

GR	0.080929
PI	0.412507
AL	0.210933
E	0.107649
RL	0.219681
F	0.166799

Table-3.116: Wald Statistics of the Simultaneous Equation Model by Taking Input Growth as Explanatory Variable: The Case of HYV Equation in case of Wheat

	GR
Chi-square	135.278*

*significant at 1%, **significant at 5%

Table-3.117: Estimated Results of Simultaneous Equation Model by Taking Input Growth as Explanatory Variable: The Case of Growth of Output Equation in case of Jowar

Variable	Coefficient	t-Statistic	Prob.
C	-104.714*	-5.2284	0
RF	0.730841*	5.165392	0
HYV	1.706976*	4.700807	0
HYV*HYV	-0.19866**	-2.00535	0.0456
AL	0.087344*	5.005674	0
RL	0.531358*	6.272671	0
PI	0.668377*	5.890289	0
E	0.511643*	7.650393	0
G	-0.51608**	-2.09429	0.0369
G*G	0.122736*	2.68428	0.0076
F	0.088933	1.11767	0.2644
M	0.045107	1.452534	0.1472
L	31.31965 *	4.868354	0
L*L	-2.4929*	-4.79239	0
Adjusted R-squared	0.93254		
F-statistic	235.4725		
Prob(F-statistic)	0		

*significant at 1%, **significant at 5%, ***significant at 10%

Table-3.118: Estimated Results of Simultaneous Equation Model by Taking Input Growth as Explanatory Variable: The Case of HYV Equation in case of Jowar

Variable	Coefficient	t-Statistic	Prob.
C	-2.29927*	-4.82248	0
GR	0.201653*	10.93504	0
PI	0.078461*	5.887813	0
AL	0.242883*	11.62509	0
E	0.088979*	4.321047	0
RL	0.065312*	10.83118	0
F	0.149683*	9.015029	0
DW	-0.70205*	-9.23257	0
Adjusted R-squared	0.97523		
F-statistic	452. 7834		
Prob(F-statistic)	0		

*significant at 1%, **significant at 5%, ***significant at 10%

Table-3.119: Marginal Effects of the Explanatory Variables from the Simultaneous Equation Model by Taking Input Growth as Explanatory Variable: The Case of Growth of Output Equation in case of Jowar

RF	0.730841
HYV	0.011675
AL	0.087344
RL	0.531358
PI	0.668377
E	0.511643
G	-0.73926
L	0.180834

Table-3.120: Wald Statistics of the Simultaneous Equation Model by Taking Input Growth as Explanatory Variable: The Case of Growth of Output Equation in case of Jowar

	HYV	**G**	**L**
Chi-square	31.56649*	8.744872**	27.16976*

***significant at 1%, **significant at 5%, ***significant at 10%**

Table-3.121: Marginal Effects of the Explanatory Variables from the Simultaneous Equation Model by Taking Input Growth as Explanatory Variable: The Case of HYV Equation in case of Jowar

GR	0.201653
PI	0.078461
AL	0.242883
E	0.088979
RL	0.065312
F	0.149683

Table-3.122: Wald Statistics of the Simultaneous Equation Model by Taking Input Growth as Explanatory Variable: The Case of HYV Equation in case of Jowar

	GR
Chi-square	69.458*

***significant at 1%, **significant at 5%**

Chapter 4

Analysis of Volatility

4.1 Introduction

The volatility in agricultural sector can either come from agricultural output or price or both. In either of these cases it will affect agricultural income through supply decision and since in Indian context nearly 70% of rural population depends on income from agricultural sector of which 47% account for poor agricultural labourer (Government of India, Planning Commission, 11th Five year plan). Such volatility will greatly affect income of the household specially of poor agricultural labourer and can be associated with a variety of factors, ranging from climate variability and change, frequent natural disasters, uncertainties in yields, weak rural infrastructure, imperfect markets and lack of financial services including limited span and design of risk mitigation instruments such as credit and insurance. Output volatility is positively correlated with negative outcomes that come from imperfectly predictable biological, climatic(rainfall) and price variables, which undermined the viability of the agriculture sector and its potential to become a part of the solution to the problem of endemic poverty of the farmers and the agricultural labor and also endangered the farmer's livelihood and income. Apart from these, there are some other variables like natural adversities (for example, pests and diseases) and climatic factors namely flood, drought etc. not within the control of the farmers, leading to adverse changes in output prices.

Before going into the detailed study one can analyse two main sources of volatility that may affect agriculture. First of all **Production volatility:** High variability of production outcomes or, production volatility is one of the main characteristic of Indian agriculture. Farmers are not able to predict correctly the amount of output that the production process will yield due to external factors such as weather, pest, and diseases. One of the main reasons of production losses is that in the time of harvesting farmers are hindered by adverse events. Secondly **Price or Market volatility:** Output price volatility is important source of market volatility in agriculture. Prices of agricultural commodities are extremely volatile. Output price variability originates from both endogenous and exogenous market shocks. Segmented agricultural markets will be influenced mainly by local supply and demand conditions while more globally integrated markets will be significantly affected by international production dynamics. In local markets, price volatility is sometimes mitigated by the "natural hedge" effect in which an increase (decrease) in annual production tends to decrease (increase) output price (though not necessarily farmers' revenues). In integrated markets, a reduction in prices is generally not correlated with local supply conditions and therefore price shocks may affect producers in a more significant way (Government of India, Planning Commission, 11th Five year plan).

Variability in crop production is predominantly owing to the volatility and uncertainty involved in production process. In the classical analysis volatility is defined as variability, which can be measured empirically. In agriculture decision of a farmer takes place at a single point of time for an uncertain future. Uncertainty, is subjective in nature and thus the probability distribution cannot be determined empirically (Heady, 1961). For empirical purpose sometime standard deviation of profit is taken as an absolute measures of volatility and the coefficient of variation is taken as the relative measures of volatility (Heady, 1952 and Dandekar,1976). Bliss and Stern(1982) used the expected utility maximization framework for analyzing risk in wheat cultivation in Palanpur district, India by assuming a linear production function. They found that the risk premium is 3.5 for land, 3.8 for fertilizer at the time of sowing, and 3.2 for ploughing. Rangaswamy(1982) using the experimental data for 1971-72 to 1973-74 estimated fertilizer response functions and computes the return(net of fertilizer cost and labour cost of application) at different levels of nitrogen per ha for each year. The standard deviation of net returns is taken as the measure of risk. Sing and Nautiyal (1986) estimate the probability distribution of the profitability of fertilizer application in HYVs of wheat and paddy crops in four different agro-climatic region of Uttar Pradesh. The risk of achieving a minimum desired return or losing money is determined from the distribution of the profitability. Sankar and Mythili(1987) indentified the factors responsible for annual variations in the proportion of net sown area to cultivated area, cropping intensity, by using simple tools such as bivariate tables, correlation analysis and decomposition exercises. Mosnier, Reynaud, Thomas, Lherm, Agabriel (2009) addressed the issue of agricultural production under both output and price risks, in the context of random climatic conditions affecting forage used in beef cattle production in France and suggest that cattle farmer exhibit constant relative risk aversion form and that climate has a significant impact on the performance of animal feeding strategies.

However, in recent econometric time series literature it is assumed that the variance of the errors will not be constant over time as in the classical case. Thus, a better specification would be to choose a model without constant variance. In the time series econometrics the variance of the random term associated with a particular endogenous variable for any particular year is expected to be correlated with the random term of that endogenous variable of the previous year. Thus the variance of the stochastic process becomes heteroscedastic. In the recent literature, variability is defined as the phenomenon of *volatility clustering* or *volatility pooling*. This characteristic shows that the current level of volatility tends to be positively correlated with its level during the immediately preceding periods. Following Engle (1982) one can estimate this phenomenon which is commonly known as the phenomenon of autoregressive conditional heteroskedasticity (ARCH). The limitation of this ARCH model is that while defining volatility of the endogenous variable at any particular point of time the variance of the random term associated with this endogenous variable only takes into account the past square value of the random term. But volatility of the endogenous variable at any particular point of time can be associated with the conditional variance of the own lag of the random term of the concerned endogenous variable as well as the square values of the random term of the previous years. This feature has been modeled by Bollerslev (1986) and Taylor (1986) and is commonly known as generalized autoregressive conditional heteroscedastic model (GARCH).

But the perusal of the literature on volatility of agricultural sector in Indian context reveals that not much attempt has been made to model volatility using the ARCH or GARCH approach of modern time series literature.

It is observed that such type of volatility can better be studied using monthly data, because if we take yearly data there is a possibility that much of the volatility can be smoothen out because of the averaging. Since the monthly data on output is not available in the Indian context the present chapter adds the literature by measuring the volatility of growth of price in case of different crops in Indian Agriculture using ARCH or GARCH approach.

The novelty of the present study may be that there is not too much literature measuring volatility of agricultural prices using ARCH/ GARCH model and also it tries to capture the effect of the variety of the crops on the agricultural price volatility.

Thus, **the objectives of the present chapter** are **first** to check whether there is any ARCH effect in the series of the growth of price indices of major selected crops or not for the period 1970-71 to 2013-14. The major selected crops and states are already defined in chapter 3. After checking the ARCH effect **next objective** is to estimate the volatility of the series of the growth of price indices of the major selected crops by applying ARCH or GARCH method. **Thirdly,** it is important to check whether different variety of each crop has any effect on the volatility or not. For this purpose we take growth of price of different variety of each crop for each of their major producing states and capture the effect of variety on the volatility by incorporating dummy variables corresponding to the variety of each crop in basic equation defining price volatility. In this context also it is interesting to check whether these varieties give more return or not.

Section 4.2 discusses the methodology and data source. In **subsection 4.2.1** the methodology for testing the presence of unit root is described. **Subsection 4.2.2** presents the method for checking the presence of ARCH/ GARCH effect. **Subsection 4.2.3** described the methodology of estimation of volatility by using autoregressive conditional heteroskedasticity model (ARCH) and generalized autoregressive conditional heteroskedastic model (GARCH). Data Sources are discussed in **4.2.4**. **Section 4.3** presents the Results of estimation and **Section 4.4 concludes.**

4.2 Methodology and Data Source

In order to employ ARCH and GARCH the first thing we need to do is to test for unit root. This is because ARCH and GARCH model can not be applicable with non stationary data.

4.2.1 Methodology for Testing the Presence of Unit Root

The methodology for testing the presence of unit root has already been discussed in detailed in the methodology section of chapter 3, so here the detailed methodology has been skipped.

4.2.2 Methodology for Testing the Presence of ARCH/ GARCH effect

The present chapter uses Brooks (2009) methodology of testing to determine whether 'ARCH-effects' are present in the residuals of an estimated model may be conducted using the following steps.

1. Run any postulated linear regression of the form given in the equation:

$$y_t = \beta_1 + \beta_2 x_{2t} + \beta_3 x_{3t} + \cdots + \beta_k x_{kt} + u_t$$

Where y_t denote the current dependent variable and x_{it} are the explanatory variables.

And save the residuals, $\widehat{u_t}$.

2. Square the residuals and regress them on own lags upto order q to test for ARCH of order q, i.e. run the regression

$$\widehat{u_t^2} = \delta_0 + \delta_1 \widehat{u_{t-1}^2} + \delta_2 \widehat{u_{t-2}^2} + \cdots + \delta_q \widehat{u_{t-q}^2} + v_t$$

where v_t is an error term of the above regression.

Obtain R^2 from this regression.

3. The test statistic is defined as TR^2 (the number of observations multiplied by the coefficient of multiple correlations) from the last regression and is distributed as a $\chi^2(q)$.

4. The null and alternative hypotheses are

$$H_0: \delta_1 = 0 \; and \; \delta_2 = 0 \; and \; \delta_3 = 0 \; and \ldots\ldots and \; \delta_q = 0$$

$$H_1: \delta_1 \neq 0 \; and \; \delta_2 \neq 0 \; and \; \delta_3 \neq 0 \; and \; \ldots\ldots and \; \delta_q \neq 0$$

Thus, the test is one of a joint null hypothesis that all q lags of the squared residuals have coefficient values that are not significantly different from zero. If the value of the test statistic is greater than the critical value from the χ^2distribution, then reject the null hypothesis. The test can also be thought of as a test for autocorrelation in the squared residuals as well as testing for the residuals of an estimated model comprising of the raw data.

4.2.3 Methodology of estimation of volatility by using ARCH or GARCH Method:

The estimation of volatility: The autoregressive conditional heteroskedasticity model (ARCH)

In autoregressive conditional heteroscedasticity model (ARCH) as proposed by Engle (1982) it is assumed that the variance of the random term of the endogenous variable (σ^2) depends on the square term of the previous year's random term. Thus the variance of the random term seems to be heteroscedastic as well as conditional on its past values. Using the ARCH model of Engle (1982) one can estimate this phenomenon. In order to understand how this model works, a definition of the conditional variance of a random variable e_t is necessary. In tune with Engle (1982) the conditional variance of e_t, (σ^2) is denoted as:

$$\sigma^2 = \text{var}(e_t / e_{t-1}, e_{t-2}, \ldots) = E[(e_t - E(e_t))^2 / e_{t-1}, e_{t-2}, \ldots] \quad (4.1)$$

Since $E(e_t) = 0$, equation (1) becomes:

$$\sigma^2 = \text{var}(e, / e_{t-1}, e_{t-2}, \ldots) = E[e^2 / e_{t-1}, e_{t-2}, \ldots] \quad (4.2)$$

Equation (4.2) shows that the conditional variance of a zero mean normally distributed random variable e_t is equal to the conditional expected value of the square of e_t. In the case of the ARCH model, the autocorrelation in volatility is modeled by:

$$\sigma^2 = \delta_0 + \delta_1 . e^2_{t-1} \quad (4.3)$$

The above model is known as ARCH(1) and it shows that the conditional variance of the error term σ^2 depends on the immediately previous value of the squared error.

To understand the problem one can think of the dependent variable y_t and the independent variable x_t satisfying the following relationship of ARCH(1) model:

$$y_t=\alpha_1+\alpha_2 x_{2t}+\alpha_3 x_{3t} + e_t \quad (4.4)$$

$$\sigma^2 =\delta_0 +\delta_1 . e^2_{t-1} \quad (4.5)$$

where $e_t \sim N(0,\sigma^2)$.

This model can be extended to the general case of ARCH(q) where the error variance depends on *q* lags of squared errors.

$$y_t=\alpha_1+\alpha_2 x_{2t}+\alpha_3 x_{3t} + e_t \quad (4.6)$$

$$\sigma^2 =\delta_0 +\delta_1 . e^2_{t-1} + \delta_2 . e^2_{t-2} +\ldots\ldots+ \delta_q . e^2_{t-q} \quad (4.7)$$

where $e_t \sim N(0,\sigma^2)$.

Since σ^2 represents the conditional variance, its value must be strictly positive otherwise it is meaningless. So all the coefficients in the conditional variance equation must be positive: $\sigma_i \geq 0$, *for all* $i = 0,1,2,...,q$.

The estimation of volatility: The generalized autoregressive conditional heteroscedastic model (GARCH)

The limitation of this ARCH model is that while defining volatility of the endogenous variable at any particular point of time the variance of the random term associated with this endogenous variable only takes into account the partial volatility. The ARCH model represents only a part of total variance because the other part which describes how the σ^2 varies over time is not captured by the ARCH model. So, in order to get the total volatility the past values of its own variances should be considered apart from the square value of the random term. This feature is commonly known as generalized autoregressive conditional heteroscedastic model (GARCH) which is developed independently by Bollerslev (1986) and Taylor (1986). The conditional variance of GARCH(1,1) model is specified as:

$$\sigma^2 = \delta_0 + \delta_1.e^2_{t-1} + \mu_1.\sigma^2_{t-1} \quad (4.8)$$

The conditional variance is explained as a sum of a long term average value (dependent on δ_0), of the information related to the volatility during the previous period ($\delta_1.e^2_{t-1}$) and of the variance of the previous period ($\mu_1.\sigma^2_{t-1}$).

The general form of the GARCH(*q*, *p*) model where the conditional variance depends on *q* lags of the squared error and *p* lags of the conditional variance can be specified as:

$$\sigma^2 = \delta_0 + \delta_1.e^2_{t-1} + \delta_2.e^2_{t-2} + \ldots + \delta_q.e^2_{t-q} + \mu_1.\sigma^2_{t-1} + \mu_2.\sigma^2_{t-2} + \ldots.. + \mu_p.\sigma^2_{t-p} \quad (4.9)$$

In practice a GARCH(1,1) model is considered to be sufficient in capturing the evolution of the volatility. A GARCH(1,1) model is equivalent to an ARCH(2) model and a GARCH(*q*, *p*) model is equivalent to an ARCH *(q + p)* model (Engle, 1982).

The unconditional variance of the error term e_t *for* GARCH (1, 1) model is constant and is given by the following equation:

$$var(e_t) = \frac{\delta 0}{1-(\delta_1+\mu_1)} \quad (4.10)$$

If $\delta_1+\mu_1<1$ then $var(e_t)>0$.

Extension of GARCH Model:

Among the many extensions of the standard GARCH models nonlinear GARCH (NGARCH) was proposed by Engle and Ng in 1993. They described the conditional covariance equation which is in the form

$\sigma_t^2 = \omega + \alpha(e_{t-1} - \theta\sigma_{t-1})^2 + \beta\sigma_{t-1}^2$ Where $\omega, \alpha, \theta, \beta > 0$

The integrated GARCH (IGARCH) is a restricted version of the GARCH model, where the sum of all the parameters sum up to one. Nelson (1991) introduced the exponential GARCH (EGARCH) model where the logarithm of the variance is important rather than the level. In the GARCH-in-mean (GARCH-M) model a heteroskedasticity term is added into the mean equation. The quadratic GARCH (QGARCH) model and the Glosten- Jagannathan- Runkle GARCH (GJR-GARCH) model (1993) can handle asymmetric effects of positive and negative shocks in the GARCH process. The threshold GARCH (TGARCH) model is similar to GJR-GARCH with the specification on conditional standard deviation instead of conditional variance. Hentschel (1995) introduced the concept of Family GARCH (FGARCH) which is an omnibus model that is a mixture of other symmetric or asymmetric GARCH models.

Estimation of GARCH Model Capturing the Effect of Variety:

In this chapter we have used ARCH (q) or GARCH (q, p) model for estimation purpose. Again to capture the effect of variety of each crop we have used EGARCH(q, p) model for estimation purpose. The EGARCH model proposed by Nelson (1991) suggested that the specification for the conditional variance is:

$$\log(\sigma_t^2) = \omega + \sum_{j=1}^{q} \beta_j \log(\sigma_{t-j}^2) + \sum_{i=1}^{p} \alpha_i \left|\frac{\epsilon_{t-i}}{\sigma_{t-i}}\right| + \sum_{k=1}^{r} \gamma_k \frac{\epsilon_{t-k}}{\sigma_{t-k}} \qquad (4.11)$$

Where

$\log(\sigma_t^2)$ is the logarithmic value of current period conditional volatility

$\log(\sigma_{t-j}^2)$ is the logarithmic value of past period’s volatility

$\left|\frac{\epsilon_{t-i}}{\sigma_{t-i}}\right|$ is the absolute value of past period’s randomness with respect to past period’s volatility for p lag.

$\frac{\epsilon_{t-k}}{\sigma_{t-k}}$ is the value of past period’s randomness with respect to past period’s volatility for r lag.

$\left|\frac{\epsilon_{t-i}}{\sigma_{t-i}}\right|$ and $\frac{\epsilon_{t-k}}{\sigma_{t-k}}$ are taken to capture the leverage effect.

So, current period conditional variance is an asymmetric function of past period's randomness.

ω is the constant term, β_j are the coefficient of past period's volatility, α_i are the coefficient of the absolute value of past period's randomness with respect to past period's volatility for p lag and γ_k are the coefficient of past period's randomness with respect to past period's volatility for r lag.

Note that the left-hand side is the log of the conditional variance. This implies that the leverage effect[1] is exponential, rather than quadratic, and that forecasts of the conditional variance are guaranteed to be nonnegative. The presence of leverage effects can be tested by the hypothesis that $\gamma_i < 0$. The impact is asymmetric if $\gamma_i \neq 0$. EViews software has been used to estimate the ARCH/ GARCH or EGARCH model.[2]

Lastly for analysis purpose the growth rate in the respective series is calculated using the formula: $log(\frac{y_t}{y_{t-1}})$

4.2.4 The Data source

The month wise data on wholesale price indices of major selected crops from April 1982 to December 2013 has been collected from the website of the Office of the Economic Adviser in

[1] Volatility tends to rise in response to "bad news", (excess returns lower than expected) and to fall in response to "good news" (excess returns higher than expected) this phenomenon is called as leverage effect.

[2] There are two differences between the EViews specification of the EGARCH model and the original Nelson model. First, Nelson assumes that the ϵ_t follows a Generalized Error Distribution (GED), while EViews gives a choice of normal, Student's t-distribution, or GED. Second, Nelson's specification for the log conditional variance is a restricted version of:

$$\log(\sigma_t^2) = \omega + \sum_{j=1}^{q} \beta_j \log(\sigma_{t-j}^2) + \sum_{i=1}^{p} \alpha_i \left(\left| \frac{\epsilon_{t-i}}{\sigma_{t-i}} \right| - E \left| \frac{\epsilon_{t-i}}{\sigma_{t-i}} \right| \right) + \sum_{k=1}^{r} \gamma_k \frac{\epsilon_{t-k}}{\sigma_{t-k}}$$

which is an alternative parameterization of the specification above. Estimating the latter model will yield identical estimates to those reported by EViews except for the intercept term ω, which will differ in a manner that depends upon the distributional assumption and the order p . For example, in a $p = 1$ model with a normal distribution, the difference will be $\alpha_1\sqrt{2/\pi}$.

the Department of Industrial Policy and Promotion, Ministry of Commerce & Industry in different base periods i.e. 1981-82, 1993-94 and 2004-05. The data on wholesale price indices of different crops from January 1980 to March 1982 has been collected from the Agricultural prices in India published by the Government of India in 1970-71 as base period. We have converted all the price indices in 1970-71 base period. The wholesale price indices of different crops from January 1970 to December 1979 are unavailable.

The data on wholesale price for different variety of each crop and each selected major producing states has been collected from the different issues of Agricultural prices in India published by the Government of India, Statistical Abstracts published by Central Statistical Organization (CSO) of India, *www.indianstat.com* (an online commercial data service), Agricultural Statistics at a Glance, and Agriculture in Brief published by the Central Statistical Organization and State Finance. Price data is unavailable for some major producing sates of different crops which are as follows:

Rice: AS and BI

Jowar: MA and RA

Gram: HA

Maize: JK

Cotton: GU, HA, MP, MA and RA

Rapeseed/Mustard: AS, GU, MP and RA

Apart from this data on wholesale price is available for only one variety for different major producing states under different crops which are as follows:

Rice: UP

Gram: BI, MA and UP

Bajra: MA

Maize: HP and UP

Groundnut: KA and TN

Rapeseed/Mustard: HA

Also wholesale price data for different variety are available from January 1970 to December 2006 in case of BI and HP and January 1970 to December 2009 in case of RA under Maize. In case of Cotton for MP and TN, data is available from January 1970 to December 1999.

Chosen varieties for each state under each crop are presented in Table 4.1.

4.3 Results of estimation

All the results of the analysis of volatility are presented in the Tables 4.2 to 4.62.

In Case of Selected Crops:

The results of unit root test, testing of ARCH effect and estimation of ARCH/GARCH model for each selected crops are presented in Table 4.2 to 4.4.

Results of Unit Root Test:

The results of ADF test, PP test and KPSS test in case of Rice, Wheat, Bajra, Gram, Jowar, Maize, Cotton, Groundnut and Rapeseed/Mustard Oil are presented in the Table 4.2.

The ADF, PP and KPSS statistics suggest that the growth rate of price index series for all crops are stationary at 1% level. So, one can estimate the volatility by applying ARCH/ GARCH method for these price series.

Results for Test of ARCH Effect:

The results for test of ARCH effect are presented in Table 4.3. The presence of ARCH effect implies that current period volatility is affected by the previous period's volatility. Now by analyzing the results it can be concluded that ARCH effects are present in the growth of price series for all selected crops. Chi-square statistics are significant at 1% level in case of Rice, Wheat, Bajra, Gram, Cotton, groundnut and Rapeseed/Mustard Oil. In case of Jowar and Maize this statistic is significant at 5% level. So, it can be concluded that for all the crops current period volatility is affected by the previous period's volatility and hence have an ARCH effect.

Results of GARCH estimation:

The results of ARCH/ GARCH estimation for each crop are presented in Table -4.4. The results indicated that a uniform model for volatility is not applicable for each crop. In case of Rice, Jowar, Maize and Rapeseed/Mustard Oil, GARCH (2, 1) model is appropriate implying that current volatility of the growth of price of these crops is affected by the previous two period's randomness of the growth of prices and the volatility of the previous period. In case of Gram and Cotton, GARCH (2, 2) model is most suitable model implying that current period volatility is affected by the previous two period's randomness of the growth of prices and also the volatility of previous two periods. In case of Wheat and Groundnut GARCH (1, 2) model is the best fitted model. In case of Bajra GARCH (1, 1) model is the suitable one and the implication is that in case of Bajra current period volatility depends upon the previous period randomness of the growth of price and volatility of the previous period.

So, it can be concluded that for all crops current period volatility of the growth of prices is not only affected by the previous month's volatility but also by the previous month's randomness of the growth of prices.

Results of the effect of Variety on the Volatility

Now after the analysis of volatility for each crop next question is that is this volatility get affected by the different variety of each crop? To answer this question growth of wholesale prices for different variety as available for each crop under each of the selected states has been considered. The results of volatility analysis by taking different variety of each crop and for each selected states are presented in Table-4.5 to 4.62.

Results of Unit Root Test:

The results of ADF test, PP test and KPSS test in case of Rice, Wheat, Jowar, Bajra, Maize, Gram, Cotton, Groundnut and Rapeseed/Mustard Oil by taking different variety for different states are presented in Table 4.5, 4.13, 4.18, 4.24, 4.33, 4.40, 4.48, 4.52 and 4.58 respectively.

Now the ADF, PP and KPSS test statistics suggest that the growth rate of price series are stationary at 1% level for all crops and states except KPSS statistic for HA in case of wheat and KA in case of groundnut. The KPSS statistics in both cases is significant at 5% level. The results of unit root test suggest that the time series are stationary and hence one can estimate ARCH or GARCH model for measuring volatility.

Results of Test of ARCH Effect:

The results of test of ARCH effect in case of Rice, Wheat, Jowar, Bajra, Maize, Gram, Cotton, Groundnut and Rapeseed/Mustard Oil by taking different variety for different states are presented in Tables 4.6, 4.14, 4.19, 4.25, 4.34, 4.41, 4.49, 4.53 and 4.59 respectively. The presence of ARCH effect implies that current period volatility is affected by the previous period's volatility. Now by analyzing the results it can be concluded that ARCH effects are present for the following states under each crop:

Rice: AP, KA, OR, PU, UP and WB

Wheat: BI, HA and UP

Jowar: GU, TN and UP

Bajra: AP, HA, KA, MA, RA, TN and UP

Maize: GU, HP, MP, PU, RA and UP

Gram: BI, MP, MA, PU, RA and UP

Cotton: AP and KA

Groundnut: AP, GU, KA and TN

Rapeseed/Mustard Oil: HA, UP and WB

Results of GARCH estimation:

All the estimated results of GARCH method for each crop and states considering different variety are presented as below.

Results of Estimation of Mean and Volatility for Rice:

For **rice,** ARCH effect exists corresponding to the states AP, KA, OR, PU, UP and WB and hence GARCH model has been estimated for rice corresponding to these above states. The estimated results of GARCH/ EGARCH model for rice corresponding to each of these six states are presented in Tables 4.7 to 4.12 respectively.

It is found that there is big difference in the number and type of existing variety for rice corresponding to each of the states. In order to introduce the effect of variety one need to incorporate dummy variable corresponding to each variety. This requires selection of a bench mark variety. For each of the state the variety for which there is minimum number of observations is selected as bench mark. The specifications of the bench mark variety for each of the state and for each of crops are presented in Table 4.1. Following the literature [Nelson (1991)] the effect of the variety on volatility is specified as follows:

$$\log(\sigma_t^2) = \omega + \underbrace{\sum_{j=1}^{q} \beta_j \log(\sigma_{t-j}^2)}_{\text{Part-A}} + \underbrace{\sum_{i=1}^{p} \alpha_i \left|\frac{\epsilon_{t-i}}{\sigma_{t-i}}\right|}_{\text{Part-B}} + \underbrace{\sum_{k=1}^{r} \gamma_k \frac{\epsilon_{t-k}}{\sigma_{t-k}}}_{\text{Part-C}} + \underbrace{\sum_{l=1}^{n} \varphi_l * Dummy\ for\ each\ variety}_{\text{Part-D}} \tag{4.11}$$

Where

$\log(\sigma_t^2)$ is the logarithmic value of current period volatility

$\log(\sigma_{t-j}^2)$ is the logarithmic value of past period's volatility

$\left|\frac{\epsilon_{t-i}}{\sigma_{t-i}}\right|$ is the absolute value of past period's randomness with respect to past period's volatility for p lag.

$\frac{\epsilon_{t-k}}{\sigma_{t-k}}$ is the value of past period's randomness with respect to past period's volatility for r lag.

$\left|\frac{\epsilon_{t-i}}{\sigma_{t-i}}\right|$ and $\frac{\epsilon_{t-k}}{\sigma_{t-k}}$ are taken to capture the leverage effect.

So, current period conditional variance is an asymmetric function of past period's randomness.

ω is the constant term, β_j are the coefficient of past period's volatility, α_i are the coefficient of the absolute value of past period's randomness with respect to past period's volatility for p lag, γ_k are the coefficient of past period's randomness with respect to past period's volatility for r lag and φ_l are the coefficient of dummy variables.

Now in the present chapter, our objective is to find out the effect of variety on the volatility of the growth of output prices. So, we are concentrating only with the explanations of sign and the statistical significance of φ_l of the equation 4.11.

In this context one point has to be made is that it is interesting to check whether these varieties give more return or not. For this purpose the estimation of the mean equation of price is needed which can jointly be estimated with the variance equation.

Since the number of variety of rice is different for each of the states and so also the bench mark dummy variable, the specified equation (4.11) will be different for each of the states. For example in case of AP under rice, three dummy variables for three varieties of crops, i.e. Coarse, Hamsalu and Akkulu has been considered in order to analyze the effect of each variety on the volatility of the growth of price. Akkulu variety of rice is taken as the bench mark dummy because it has the minimum number of observations. Now the estimated mean and variance equation for AP is as follows:

Mean Equation for Growth of Price:

Mean= C(1)*DC + C(2)* DH+ Constant

Where

DC and DH are the dummy variable for coarse and hamsalu variety of rice.

C(1) and C(2) are the coefficient of the dummy variables.

Variance Equation for Growth of Price:

LOG(GARCH)=C(3)+C(4)*ABS(RESID(-1)/@SQRT(GARCH(-1)))+C(5)*RESID(-1)/@ SQRT(GARCH(-1)) + C(6)*LOG(GARCH(-1)) + C(7)*LOG(GARCH(-2)) + C(8)*DC + C(9)*DH

Where,

ABS(RESID(-1)/@SQRT(GARCH(-1))) represents part-B of the equation 4.11.

RESID(-1)/@ SQRT(GARCH(-1)) represents part-C of the equation 4.11.

LOG(GARCH(-1)) and LOG(GARCH(-2)) represent part-A of the equation 4.11.

DC and DH are the dummy variable for coarse and hamsalu variety of rice (part-D).

And C(3) to C(7) are the parameters of the variance equation. C(8) and C(9) are the coefficient of the dummy variables for coarse and hamsalu respectively.

Now if the coefficient of dummy for coarse and hamsalu is positive and statistically significant then it can be concluded that coarse and hamsalu variety have more effect on the volatility than the akkulu variety of rice in case of AP. In other wards it can be concluded that volatility of the growth of price is more in case of coarse and hamsalu than akkulu for AP of rice. Again from the estimated mean equation it can be suggested that as the coefficient of dummy associated with coarse and hamsulu turned out to be positive and statistically significant, these two variety has a positive and significant effect on the mean of the growth of price in case of AP under rice. Akkulu being the bench mark variety, it in turn implies that coarse and hamsulu variety give more return than akkulu.

From the results of estimation of rice as presented in Tables 4.7 to 4.12, it can be concluded that in case of AP, the coefficient of coarse and hamsalu variety dummies has positive and significant effect on the volatility of the growth of price for rice implying that these two variety of rice has more positive and significant effect on the volatility of the growth of price than akkalu variety. The results of mean equation are also representing this fact that Coarse and hamslu has positive and significant effect on the mean of the growth of price in case of AP. It in turn implies that these two varieties generate more return than akkalu.

In case of KA there are three variety fine, IR-8 and coarse, the benchmark variety being IR-8. The coefficient of fine and coarse variety dummy is positive and significant implying that fine and coarse has more significant and positive effect on volatility of growth of price for rice than IR-8 because in case of KA, IR-8 has been taken as the benchmark variety. These two varieties give more return than the IR-8 because the coefficient of dummies of these two varieties is positive and statistically significant in the mean equation in case of KA.

In case of OR, fine, common and coarse are taken as the different varieties of rice. Among them, common variety is taken as the benchmark variety. The coefficient of fine and coarse dummy is positive and statistically significant in the variance equation implying that these two varieties has greater effect on the volatility of the growth of price than common variety. Again the coefficient of dummy is positive and statistically significant in the mean equation for fine and coarse in case of OR implying that these varieties of rice give more return than the common variety in case of OR.

For PU, fine, common and basmati are the three varieties of rice and common variety of rice is the benchmark dummy of rice. Now, the coefficient of the dummy variable for fine and basmati has significant and positive effect on the volatility of the growth of price of rice than the common variety because the coefficients of these two dummies are positive and statistically significant. Again the coefficient of dummy is positive and statistically significant in the mean equation for fine and basmati in case of PU implying that these varieties of rice give more return than the common variety in PU.

In case of UP, we cannot analyze the effect of the variety on the volatility of the growth of price of rice because in this state there is only one variety of rice i.e. coarse-III. Thus for UP we have estimated EGARCH (p,q), ARCH (p,q) and GARCH (p,q) model without dummy variable and found that EGARCH (1,1) model is the best fitted model.

Again the coefficient of dummy for coarse variety of rice is positive and statistically significant in the variance equation implying that coarse variety of rice has more significant and positive effect on the volatility of growth of price than common in case of WB because again common variety of rice has been taken as the bench mark variety for WB. From the results of the mean equation it can be concluded that, the coefficient of dummy for coarse variety is positive and statistically significant. So it can be inferred that in case of WB coarse variety of rice gives more return than common variety of rice.

Thus, it can be concluded that under rice nature of volatility varies from state to state because different volatility model is the best fitted model for different states. Apart from this the causes behind the source of volatility varies across the states

Results of Estimation of Mean and Volatility for Wheat:

In case of wheat the results of GARCH/ EGARCH estimation are presented in Table-4.15 to 4.17.

In case of BI white variety of wheat has more effect on the volatility of the growth of price of wheat than FAQ variety because the coefficient of dummy variable for white variety is positive and statistically significant in the variance equation. In case of BI FAQ variety of wheat has chosen as the benchmark variety. Similarly, in the mean equation the coefficient dummy for white variety is positive and statistically significant implying that white variety give more return.

In case of HA, there are two varieties of wheat namely dara and Mexican and Mexican variety is taken as the bench mark variety. Now, for HA dara variety of wheat has more effect on the volatility of growth of wheat than Mexican variety because the coefficient of dummy variable for dara is positive and statistically significant. In the mean equation also the coefficient of dummy for dara is positive and statistically significant implying that dara gives more return than the Mexican variety in case of wheat for HA.

Lastly, in case of UP in the variance equation the coefficient of dummy for white and imported variety is positive and statistically significant implying that these two varieties have more effect than dara variety. For UP, dara variety of wheat is taken as the bench mark variety. Again in the mean equation the coefficient of dummy for white variety of wheat is positive and statistically significant implying that white variety give more return than the dara in case of UP.

Thus like rice, in case of wheat nature of volatility varies from state to state because different volatility model is the best fitted model for different states. Apart from this different variety of wheat is the source of volatility for different states.

Results of Estimation of Mean and Volatility for Jowar:

In case of jowar all the results of GARCH/ EGARCH estimation incorporating the dummy corresponding to each variety are presented in Tables-4.20 to 4.22.

The white variety of jowar is taken as the benchmark variety of jowar in case of GU. Now, from the results of the variance equation it can be concluded that the coefficient of dummy for yellow is positive and statistically significant implying that in case of GU, yellow variety of jowar has more effect than white variety on the volatility of growth of price of jowar. Here white variety is taken as the benchmark variety. Again from the mean equation, it can be concluded that yellow variety give more return than the white because the coefficient of dummy for yellow is positive and statistically significant.

In case of TN, taking white as the bench mark variety it can be concluded that red variety has more effect than the white on the volatility of the growth of jowar because the coefficient of dummy for red is positive and statistically significant in the variance equation. In the mean equation, the coefficient of dummy for red is positive and statistically significant. The implication of the result is the same as discussed above.

In case of UP we get the reverse result. Here white variety of jowar has more effect on the volatility of growth of price of jowar than red variety. Not only this, white variety gives more return than the red variety.

Results of Estimation of Mean and Volatility for Bajra:

In case of bajra all the results of GARCH/ EGARCH estimation are presented in Tables-4.25 to 4.31.

In case of AP there are two types of variety of bajra local and hybrid among which hybrid variety of bajra is taken as the benchmark variety. Now, from the variance equation it can be concluded that the coefficient of dummy for local variety is positive and statistically significant implying that local variety of bajra has more effect than the hybrid variety on the volatility of the growth of price. From the mean equation the results suggest that the coefficient dummy for local variety is positive and statistically significant implying that local variety of bajra give more return than the hybrid variety in case of AP.

In case of HA, coarse and desi has more significant positive effect on the volatility of the growth of price than hybrid because the coefficient of dummy for coarse and desi is positive and statistically significant in the variance equation. Here hybrid is taken as the benchmark variety. In the mean equation the coefficient of dummy for coarse and desi is positive and statistically significant implying that these two varieties provide more return than the hybrid variety of bajra for HA.

Again by taking hybrid variety as the benchmark variety in case of KA from the variance equation it can be concluded that the dummy for superior variety of bajra is positively and significantly related with the volatility of the growth of bajra. This result reveals that superior variety of bajra has more effect on the volatility of the growth of price than the hybrid variety in case of KA. From the results of the mean equation it can be concluded that the coefficient of dummy for superior variety is positive and statistically significant implying that superior variety of bajra offers more return than the hybrid variety.

In case of RA, the growth of price of bajra is more affected by local and small variety than coarse which is the benchmark variety for RA because the coefficient of dummy for local and small variety of bajra is positive and statistically significant in the variance equation. In the mean equation, the coefficient of dummy for these two varieties is positive and statistically significant implying that return from these two varieties of bajra is more than the coarse variety of bajra in case of RA.

For TN, again local variety has more effect on the volatility of growth of price of bajra than the arsi variety as the coefficient of dummy variable for local variety is positive and statistically significant in the variance equation. In case of KA arsi variety of bajra is taken as the benchmark variety. The coefficient of dummy for local variety is also positive and statistically significant in the mean equation.

In case of UP the volatility in the growth of price of bajra is less affected by dara variety than local and FAQ variety because the coefficient of dummy variable for local and FAQ varieties are positive and statistically significant in the variance equation. In this state, dara is the benchmark variety. Also local and FAQ variety prop up more return than the local variety.

Results of Estimation of Mean and Volatility for Maize:

All the results of the GARCH/ EGARCH estimation in case of maize are presented in the Tables-4.34 to 4.39.

Considering white variety of maize as benchmark variety in case of GU, it can be concluded that the volatility of the growth of price is more affected by the yellow variety of maize than white variety because the coefficient of dummy in case of yellow is positive and statistically significant in the variance equation. In the mean equation the coefficient of dummy for yellow is positive and statistically significant implying that yellow variety of maize give more return than the white variety of maize in case of GU.

The reverse is true in case of MP where white has more positive and significant effect on the volatility of the growth of price of maize than yellow variety. The reverse result is also true for the mean equation.

Similarly, coarse variety maize has positive and significant effect on the volatility of the growth of price than local variety in case of PU because the coefficient of dummy for coarse variety is positive and statistically significant in the variance equation. In case of PU local is chosen as the benchmark variety. In the mean equation the coefficient of dummy for coarse is positive and statistically significant implying that coarse variety has more effect on the return than the local variety of maize in case of PU.

In case of RA chosen varieties under maize are local, red, coarse and yellow where yellow is taken as the benchmark variety. Now from the results of the variance equation it can be concluded that the coefficients of dummies for local, red and coarse are positive and statistically significant suggesting that these three varieties have more effect on the volatility of the growth of price than yellow variety. Similarly, from the results of the mean equation it can be concluded that the coefficient of dummies of the local, red and coarse give more return than the yellow variety of maize in case of RA.

Results of Estimation of Mean and Volatility for Gram:

In case of gram all the results of GARCH/ EGARCH estimation are presented in Tables-4.42 to 4.47.

By taking No.-III as the benchmark variety it can be stated that the volatility of the growth of price for gram is more affected by the desi variety than No.-III for MP because the coefficient of dummy variable for desi is significant and positive in the variance equation. In the mean equation, the coefficient of dummy is positive and statistically significant for desi. The implication of this result is the same as in the earlier cases.

In case of PU, desi and black variety of gram has been considered and black variety of gram is chosen as the bench mark variety. From the results of the variance equation, it can be concluded that the coefficient of dummy for desi is positive and significant implying that desi variety of gram has more effect on the volatility than the black variety in case of PU. From the mean equation it can be concluded that desi variety give more return than the black variety of gram as the coefficient of dummy for desi is positive and significant.

In case of RA, FAQ variety has significant and positive effect on the volatility of the growth of price for gram than the local variety not only this, from the mean equation the conclusion can be made that FAQ variety of gram give more return in case of RA. For RA local variety of gram is chosen as the benchmark variety.

In case of BI, MA and UP GARCH (2, 2), EGARCH (1, 1) and GARCH (1, 2) respectively are the best fitted model. For all these three states there is only one variety of gram. So, for these three states comparison between different varieties is not possible.

Results of Estimation of Mean and Volatility for Cotton:

In case of cotton all the results of GARCH/ EGARCH estimation are presented in Tables-4.50 to 4.52.

Under cotton laxmi and hybrid are the two varieties of cotton in case of AP. For AP, hybrid variety of cotton is chosen as the benchmark variety of cotton. Now, in case of AP in the variance equation the coefficient of dummy of laxmi is positive and statistically significant implying that laxmi variety of cotton has the more effect on the volatility of the growth of cotton than the hybrid quality. Again the result of the mean equation shows that laxmi variety of cotton give more return than the hybrid variety because the coefficient of dummy is positive and significant in the mean equation.

For KA, laxmi and banni are the two varieties of cotton and banni variety is taken as the benchmark variety. From the results of the variance equation it can be said that laxmi variety of cotton has more effect on the volatility of the growth of price than banni variety as the coefficient of the dummy for laxmi is positive and statistically significant. In case of mean equation the coefficient of dummy for laxmi is positive and significant implying that laxmi variety of cotton give more return than the banni variety of cotton in case of KA.

Results of Estimation of Mean and Volatility for Groundnut:

All the results of the GARCH/ EGARCH estimation are presented in Tables-4.54 to 4.57 in case of groundnut.

In case of AP, pods variety groundnut has more positive effect on the volatility of growth of price of groundnut than kernel variety as in the variance equation the coefficient of dummy for pods is positive and statistically significant and kernel variety of groundnut is taken as the benchmark variety. The coefficient of dummy for pods is also positive and statistically significant in the mean equation implying that pods variety gives more return than the kernel variety in case of AP.

For GU shell variety of groundnut has more effect on the volatility than bold because in the variance equation the coefficient of dummy for shell variety is positive and significant. On the other hand, in the mean equation, also the coefficient of dummy for shell variety is positive and statistically significant. The implication of this result is similar to the earlier results.

In case of KA and TN there is only one variety and EGARCH (3, 3) and GARCH (1, 1) respectively are the best fitted model for these two states.

Results of Estimation of Mean and Volatility for Rapeseed/Mustard Oil:

All the results of GARCH/ EGARCH estimation has been presented in the Tables-4.60 to 4.62.

In case of HA there is only one variety i.e. sarson and GARCH (2, 2) model is the best fitted model.

The volatility of the growth of price of Rapeseed/Mustard Oil is more affected by lahi and laha variety than yellow variety for UP and yellow, fresh and desi than rai variety for WB. Because the coefficient of dummy variables are positive and statistically significant in the variance equation for lahi and laha variety in case of UP and for yellow, fresh and desi variety in case of WB. In the mean equation the coefficient of dummy are positive and significant for these varieties for both states implying that these varieties give more return than the corresponding benchmark variety for these two states.

So in summary, it can be concluded that under each crop different models of volatility is found to be the best fitted model for different states. So volatility of growth of price varies from state to state under a certain crop also. This strong state-wise variation in the volatility in the growth of price is mainly due to the different varieties because different varieties of crop have significant and positive effect on volatility of the growth of price for different states. The estimated mean equations for different states also reveals that these varieties of crops have positive and significant effect on the return series of the growth of price for different selected crops.

4.4. Conclusion

The present chapter analyses the output price volatility for the major selected crops of Indian agriculture. The main objectives of this chapter are to check whether there is any ARCH effect in the series of price indices of major selected crops or not for the period 1970-71 to 2013-14. After checking the ARCH effect next objective is to estimate the volatility of the series of price indices of the major selected crops by applying ARCH or GARCH method. Now, after analyzing the volatility of the major selected crops next it is important to check whether different variety of each crop has any effect on the volatility or not and for this purpose we have taken price of different variety of each crop for each of their major producing states and analyses the volatility of output price by applying ARCH/ GARCH method. Further, from the study it is also possible to find out which variety gives more return as compared to the other.

The results suggest that the growth rates of price index series for all crops are stationary at 1% level and for all the crops current period volatility is affected by the previous period's volatility, ie., ARCH effect is common for the growth of price index series for all crops. The results of GARCH estimation suggest that nature of volatility is not common for all the crops because it varies from crop to crop and not only this for all crops current period volatility is not only get affected by the volatility of previous months but also by the volatility of previous month's randomness.

Now if one considers the effect of variety then the results of unit root and checking of ARCH effect suggests that the growth of price series are stationary at 1% level for all crops and states except KPSS statistic for HA for wheat and KA for groundnut. The KPSS statistics in both cases is significant at 5% level and ARCH effects are present for the following states under each crop: Rice: AP, KA, OR, PU, UP and WB; Wheat: BI, HA and UP; Jowar: GU, TN and UP; Bajra: AP, HA, KA, MA, RA, TN and UP; Maize: GU, HP, MP, PU, RA and UP; Gram: BI, MP, MA, PU, RA and UP; Cotton: AP and KA; Groundnut: AP, GU, KA and TN and Rapeseed/Mustard Oil: HA, UP and WB.

From the study it can thus be concluded that the following variety gives more return and also affect the volatility of the growth of output price in positive direction for each of the states and crops which are as follows:

- Rice: AP: Coarse and Hamsalu; KA: Fine and Coarse; OR: Fine and Coarse; PU: Fine and Basmati; WB: Coarse
- Wheat: BI: White; HA: Dara; UP: White and Imported
- Jowar: GU: Yellow; TN: Red; UP: White
- Bajra: AP: Local; HA: Coarse and Desi; KA: Superior; RA: Loacl and Small; TN: Local; UP: Local and FAQ
- Maize: GU: Yellow; MP: White; PU: Coarse; RA: Local, Red and Coarse
- Gram: MP: Desi; PU: Desi; RA: FAQ
- Cotton: AP: Laxmi; KA: Laxmi
- Groundnut: AP: Pods; GU: Shell
- Rapeseed/ Mustard Oil: UP: Lahi and Laha; WB: Yellow, Fresh and Desi

Thus, the results of GARCH/ EGARCH estimation points out that there exists a strong state-wise variation in terms of volatility under a certain crop as best fitted volatility model for the growth of output prices varies from state to state under a certain crop. The main reason behind this strong state-wise variation in the volatility of the growth of price is mainly due to the different varieties because different varieties of crop have significant and positive effect on volatility for different states. The estimated mean equations for different states also represent the fact that these varieties of crops have positive and significant effect on the return series of the growth of price for different selected crops.

Thus the analysis reveals that in order to control for the volatility in the growth of output price a common policy for all crops and all states are not suitable because the nature of

volatility varies from crop to crop and state to state. The variation of the volatility mainly comes from the different varieties of the growth of output prices for different crops. So, in order to decrease the volatility in the output price central or states Governments have to control the output price of that specific variety which is actually main cause of the volatility of that crop.

Table-4.1: Chosen Variety for each States under Each Crop and the Benchmark Variety

Crops	States	Variety	Benchmark Variety	Reasons for taking Bench Mark
Rice	AP	Coarse, Hamsalu and Akkulu	Akkulu	Minimum Number of Observations
	HA	Coarse	NA	
	KA	Fine, IR-8 and Coarse	IR-8	Minimum Number of Observations
	MP	Coarse, Inferior and IR-8	IR-8	Minimum Number of Observations
	OR	Fine, Coarse and Common	Common	Minimum Number of Observations
	PU	Fine, Basmati and Common	Common	Minimum Number of Observations
	TN	Coarse and IR-20	IR-20	Minimum Number of Observations
	UP	Coarse-III	NA	
	WB	Coarse and Common	Common	Minimum Number of Observations
Wheat	BI	White and FAQ	FAQ	Minimum Number of Observations
	HA	Dara and Mexican	Mexican	Minimum Number of Observations
	MP	Coarse-Pisi, Medium and Fine	Fine	Minimum Number of Observations
	PU	Mexican-Red and PBW-343	PBW-343	Minimum Number of Observations
	UP	White, Imported and Dara	Dara	Minimum Number of Observations
	RA	Farm and Kalyan	Kalyan	Minimum Number of Observations
Jowar	AP	White and Yellow	White	Minimum Number of Observations
	GU	White and Yellow	White	Minimum Number of Observations
	KA	White, Hybrid and Gabi	Gabi	Minimum Number of Observations
	TN	Red and White	White	Minimum Number of Observations
	UP	Red and White	Red	Minimum Number of Observations
Gram	BI	Desi	NA	
	MP	Desi and No.-III	No.-III	Minimum Number of Observations
	MA	Yelloe	NA	
	PU	Desi and Black	Black	Minimum Number of Observations
	RA	FAQ and Local	Local	Minimum Number of Observations
	UP	Desi	NA	
Bajra	AP	Local and Hybrid	Hybrid	Minimum Number of Observations
	GU	Desi and Hybrid	Hybrid	Minimum Number of Observations
	HA	Coarse, Desi and Hybrid	Hybrid	Minimum Number of Observations
	KA	Supirior and Hybrid	Hybrid	Minimum Number of Observations
	MA	Local	NA	
	RA	Local, Small and Coarse	Coarse	Minimum Number of Observations
	TN	Local and Arsi	Arsi	Minimum Number of Observations
	UP	Local, FAQ and Dara	Dara	Minimum Number of Observations
Maize	AP	Red and Unspecified	Unspecified	Minimum Number of Observations
	BI	Red and White	White	Minimum Number of Observations
	GU	Yellow and White	White	Minimum Number of Observations
	HP	Local	NA	
	KA	Hybrid and HX	HX	Minimum Number of Observations
	MP	White and Yellow	Yellow	Minimum Number of Observations

	PU	Coarse and Local	Local	Minimum Number of Observations
	RA	Local, Red, Coarse and Yellow	Yellow	Minimum Number of Observations
	UP	White	NA	
Groundnut	AP	Pods and Kernel	Kernel	Minimum Number of Observations
	GU	Shell and Bold	Bold	Minimum Number of Observations
	TN	Without Shell	NA	
	KA	Small	NA	
	MP	Small, Pods and Bold	Bold	Minimum Number of Observations
Rapeseed/Mustard	HA	Sarson	NA	
	UP	Lahi, Yellow and Laha	Laha	Minimum Number of Observations
	WB	Yellow, Fresh, Rai and Desi	Rai	Minimum Number of Observations
Cotton	AP	Laxmi and Hybrid	Hybrid	Minimum Number of Observations
	KA	Laxmi and Banni	Banni	Minimum Number of Observations
	PU	Desi and F-414	F-414	Minimum Number of Observations

NA: NOT APPLICABLE

Table-4.2: Results of Unit Root Test for Each Crop

Crops	ADF		PP		KPSS
	Statistics	P-value	Statistics	P-value	Statistics
Rice	-11.9606*	0	-11.1029*	0	0.080966*
Wheat	-13.3838*	0	-11.8434*	0	0.064775*
Jowar	-13.9457*	0	-14.6912*	0	0.026103*
Bajra	-7.8912*	0	-14.3116*	0	0.028122*
Maize	-13.8046*	0	-13.5355*	0	0.031645*
Gram	-9.24319*	0	-11.3544*	0	0.035049*
Cotton	-13.4575*	0	-13.4329*	0	0.033057*
Groundnut	-13.664*	0	-13.911*	0	0.073641*
Rapeseed/Mustard	-12.3655*	0	-12.3918*	0	0.03793*

***significant at 1%, **significant at 5%, ***significant at 10%**

Table-4.3: Results of ARCH Effect for Each Crop

Crops	Chi-Squared Statistics	P-value
Rice	41.86178*	0.00000006
Wheat	45.557283*	0.00000001
Jowar	12.651751**	0.02687024
Bajra	21.247165*	0.00072742
Maize	12.117938**	0.03320701
Gram	36.347436*	0.00000081
Cotton	33.149773*	0.00000351
Groundnut	17.830356*	0.0031667
Rapeseed/Mustard	16.378583*	0.00584235

***significant at 1%, **significant at 5%, ***significant at 10%**

Table-4.4: Results of ARCH/GARCH Estimation for Each Crop

	Rice			Wheat		
	Coefficient	**Z-Statistics**	**P-Value**	**Coefficient**	**Z-Statistics**	**P-Value**
C	8.03E-06***	1.688092	0.0914	7.75E-05*	3.629834	0.0003
RESID(-1)^2	0.04361*	3.219552	0.0013			
RESID(-2)^2	0.003337**	2.538495	0.0111	0.398166*	5.120333	0
GARCH(-1)	0.919948*	20.56985	0	0.299315***	1.646196	0.0997
GARCH(-2)				0.269718***	1.723606	0.0848
	Jowar			**Bajra**		
	Coefficient	**Z-Statistics**	**P-Value**	**Coefficient**	**Z-Statistics**	**P-Value**
C	4.52E-06	0.497342	0.6189	0.000694***	1.910893	0.056
RESID(-1)^2	0.095126*	5.52948	0	0.121902**	2.098557	0.0359
RESID(-2)^2	0.008707*	4.905488	0			
GARCH(-1)	0.870724*	7.01901	0	0.44606***	1.788142	0.0738
GARCH(-2)						
	Maize			**Gram**		
	Coefficient	**Z-Statistics**	**P-Value**	**Coefficient**	**Z-Statistics**	**P-Value**
C	2.25E-07	0.03268	0.9739	0.000105***	1.726387	0.0843
RESID(-1)^2	0.221733*	3.548408	0.0004	0.256858*	3.952268	0.0001
RESID(-2)^2	0.196904*	3.04311	0.0023	0.17129**	2.501161	0.0133
GARCH(-1)	0.474154*	3.04688	0.0021	0.276461**	2.069149	0.0385
GARCH(-2)				0.100691***	1.862001	0.0626
	Cotton			**Groundnut**		
	Coefficient	**Z-Statistics**	**P-Value**	**Coefficient**	**Z-Statistics**	**P-Value**
C	8.53E-05***	1.809932	0.0703	0.000206***	1.89661	0.0579
RESID(-1)^2	0.251305*	5.782599	0	0.108672**	2.047115	0.0406
RESID(-2)^2	0.190548*	5.019776	0			
GARCH(-1)	0.370944*	13.86172	0	0.004621*	4.044559	0
GARCH(-2)	0.138702*	4.273458	0	0.747749*	5.135612	0
	Rapeseed/Mustard					
	Coefficient	**Z-Statistics**	**P-Value**			
C	4.57E-05**	2.240917	0.025			
RESID(-1)^2	2.23E-01*	2.687227	0.0072			
RESID(-2)^2	0.164206***	1.957483	0.0503			
GARCH(-1)	0.518037*	14.4023	0			
GARCH(-2)						

***significant at 1%, **significant at 5%, ***significant at 10%**

Table-4.5: Results of Unit Root Test for Each States In Case of Rice

	ADF	P-VALUE	PP	P-VALUE	KPSS
AP	-32.1104*	0	-33.6826*	0	0.035421*
HA	-24.249*	0	-24.4478*	0	0.02089*
OR	-19.3116*	0	-58.427*	0.0001	0.047325*
PU	-24.3076*	0	-49.5904*	0.0001	0.06694*
WB	-20.7534*	0	-21.3273*	0	0.031602*
KA	-24.9464*	0	-25.4505*	0	0.042217*
UP	-14.8473*	0	-34.8286*	0	0.070191*
MP	-27.8322*	0	-27.9094*	0	0.035736*
TN	-24.5704*	0	-24.6496*	0	0.052707*

***significant at 1%, **significant at 5%, ***significant at 10%**

Table-4.6: Results of ARCH Effect for Each States In Case of Rice

STATES	CHI-SQUARED VALUE	P-VALUE
AP	37.61057*	4.5E-07
HA	0.171888	0.999387
KA	43.675511*	3E-08
MP	4.803749	0.440297
OR	215.263249*	0
PU	203.940097*	0
TN	0.310893	0.997433
UP	207.259032*	0
WB	66.620741*	0

***significant at 1%, **significant at 5%, ***significant at 10%**

Table-4.7: Results of ARCH/GARCH Estimation In Case AP Under Rice

LOG(GARCH) = C(3) + C(4)*ABS(RESID(-1)/@SQRT(GARCH(-1))) + C(5)*RESID(-1)/@SQRT(GARCH(-1)) + C(6)*LOG(GARCH(-1)) + C(7)*LOG(GARCH(-2)) + C(8)*DC + C(9)*DH

Variable	**Coefficient**	**Std. Error**	**z-Statistic**	**Prob.**
Mean Equation				
DC	0.06845*	0.013728	4.9861597	0
DH	0.420433*	0.0745063	5.6429188	0
C	0.389676	0.446629	0.872482	0.3829
Variance Equation				
C(3)	0.033311*	0.0019189	17.359425	0
C(4)	0.074788*	0.011815	6.3299196	0
C(5)	0.056112*	0.013905	4.035383	0
C(6)	0.093671*	0.01648	5.6839199	0
C(7)	0.070304*	0.031107	2.2600701	0
C(8)	0.171714*	0.028666	5.9901626	0
C(9)	0.170444*	0.027787	6.1339475	0

***significant at 1%, **significant at 5%, ***significant at 10%;**
DC and DH are the dummies for Coarse and Hamsalu variety.

Table-4.8: Results of ARCH/GARCH Estimation In Case KA Under Rice

LOG(GARCH) = C(3) + C(4)*ABS(RESID(-1)/@SQRT(GARCH(-1))) + C(5)*RESID(-1)/@SQRT(GARCH(-1)) + C(6)*LOG(GARCH(-1)) + C(7)*DC +C(8)*DF

Variable	**Coefficient**	**Std. Error**	**z-Statistic**	**Prob.**
Mean Equation				
DC	0.36351*	0.08454	4.29976	0
DF	0.73913*	0.0917	8.0605	0
C	0.720561*	0.101749	7.081715	0
Variance Equation				
C(3)	0.11672*	0.03356	3.47845	0.0005
C(4)	0.3344*	0.02349	14.2382	0
C(5)	0.13364*	0.02662	5.02036	0
C(6)	0.10417*	0.01012	10.2952	0
C(7)	0.00617*	0.00038	16.1916	0
C(8)	0.171871*	0.025694	6.689108	0

***significant at 1%, **significant at 5%, ***significant at 10%**
DC and DF are the dummies for Coarse and Fine variety.

Table-4.9: Results of ARCH/GARCH Estimation In Case OR Under Rice

LOG(GARCH) = C(3) + C(4)*ABS(RESID(-1)/@SQRT(GARCH(-1))) + C(5) *ABS(RESID(-2)/ @SQRT(GARCH(-2))) + C(6)*RESID(-1)/@SQRT(GARCH(-1)) + C(7)*LOG(GARCH(-1)) + C(8)*DC + C(9)*DF

Variable	Coefficient	Std. Error	z-Statistic	Prob.
Mean Equation				
DC	0.15209**	0.0536	2.83755	0.024
DF	0.67033**	0.33974	1.97304	0.0485
C	0.643826***	0.349268	1.84336	0.0653
Variance Equation				
C(3)	0.04869*	0.01508	3.22835	0
C(4)	0.06959***	0.04094	1.69985	0.0892
C(5)	0.19854*	0.0532	3.73192	0
C(6)	0.16723*	0.03412	4.90166	0
C(7)	0.15829*	0.04838	3.27174	0
C(8)	0.06691*	0.0038	17.6272	0
C(9)	0.08196*	0.01782	4.59866	0

***significant at 1%, **significant at 5%, ***significant at 10%**
DC and DF are the dummies for Coarse and Fine variety

Table-4.10: Results of ARCH/GARCH Estimation In Case PU Under Rice

LOG(GARCH) = C(3) + C(4)*ABS(RESID(-1)/@SQRT(GARCH(-1))) + C(5)*RESID(-1)/@SQRT(GARCH(-1)) + C(6)*LOG(GARCH(-1)) + C(7)*DB +C(8)*DF

Variable	Coefficient	Std. Error	z-Statistic	Prob.
Mean Equation				
DB	0.5237*	0.16343	3.20442	0
DF	0.12933*	0.02234	5.78952	0
C	0.82499	0.789301	1.045216	0.2959
Variance Equation				
C(3)	0.13706*	0.01253	10.9429	0
C(4)	0.12042*	0.03767	3.19682	0
C(5)	0.17534*	0.02505	6.99892	0
C(6)	0.06712*	0.01693	3.96456	0
C(7)	0.17485*	0.02168	8.06532	0
C(8)	0.16195*	0.01356	11.9448	0

***significant at 1%, **significant at 5%, ***significant at 10%**
DB and DF are the dummies for Basmati and Fine variety

Table-4.11: Results of ARCH/GARCH Estimation In Case UP Under Rice

LOG(GARCH) = C(1) + C(2)*ABS(RESID(-1)/@SQRT(GARCH(-1)))+ C(3)*RESID(-1)/@SQRT(GARCH(-1)) + C(4)*LOG(GARCH(-1))

Variable	Coefficient	Std. Error	z-Statistic	Prob.
Variance Equation				
C(1)	0.19063*	0.04089	4.66225	0
C(2)	0.2854*	0.03083	9.25595	0
C(3)	0.24261*	0.0309	7.85044	0
C(4)	0.14604*	0.03554	4.10972	0

***significant at 1%, **significant at 5%, ***significant at 10%**

Table-4.12: Results of ARCH/GARCH Estimation In Case WB Under Rice

LOG(GARCH) = C(2) + C(3)*ABS(RESID(-1)/@SQRT(GARCH(-1))) + C(4)*RESID(-1)/@SQRT(GARCH(-1)) + C(5)*LOG(GARCH(-1)) + C(6)*DC

Variable	Coefficient	Std. Error	z-Statistic	Prob.
Mean Equation				
DC	0.008166*	0.003149	2.593336	0.0095
C	0.006188***	0.003622	1.708581	0.0875
Variance Equation				
C(2)	0.249*	0.0276867	8.9935	0
C(3)	0.15795*	0.0312951	5.04712	0
C(4)	0.20384*	0.0244345	8.3423	0
C(5)	0.16467*	0.0320921	5.13117	0
C(6)	0.14264***	0.0764019	1.86697	0.0785

***significant at 1%, **significant at 5%, ***significant at 10%**
DC is the dummy for coarse variety

Table-4.13: Results of Unit Root Test for Each States In Case of Wheat

	ADF	P-VALUE	PP	P-VALUE	KPSS
BI	-16.4316*	0	-26.057*	0	0.033049*
HA	-12.827*	0	-36.7735*	0	0.113145**
MP	-25.0349*	0	-26.6913*	0	0.025481*
PU	-22.3514*	0	-23.1943*	0	0.023421*
RA	-23.7846*	0	-24.5191*	0	0.030272*
UP	-17.7228*	0	-25.0162*	0	0.040644*

***significant at 1%, **significant at 5%, ***significant at 10%**

Table-4.14: Results of ARCH Effect for Each States In Case of Wheat

STATES	CHI-SQUARED VALUE	P-VALUE
BI	9.439608***	0.092763
HA	49.348502*	0
MP	5.379581	0.371331
PU	0.676504	0.984233
RA	1.121745	0.952161
UP	31.300779*	8.17E-06

***significant at 1%, **significant at 5%, ***significant at 10%**

Table-4.15: Results of ARCH/GARCH Estimation In Case BI Under Wheat

LOG(GARCH) = C(2) + C(3)*ABS(RESID(-1)/@SQRT(GARCH(-1))) + C(4)*RESID(-1)/ @SQRT(GARCH(-1)) + C(5)*LOG(GARCH(-1)) + C(6)*DW

Variable	Coefficient	Std. Error	z-Statistic	Prob.
Mean Equation				
DW	0.258*	0.04913	5.251374	0
C	0.579087	0.631674	0.916751	0.3593
Variance Equation				
C(2)	0.08019*	0.01042	7.69947	0
C(3)	0.02192*	0.00459	4.77308	0
C(4)	0.25528*	0.0583	4.37849	0
C(5)	0.22063*	0.05257	4.19724	0
C(6)	0.26581*	0.05082	5.23003	0

***significant at 1%, **significant at 5%, ***significant at 10%**
DW is the dummy for white variety

Table-4.16: Results of ARCH/GARCH Estimation In Case HA Under Wheat

LOG(GARCH) = C(2) + C(3)*ABS(RESID(-1)/@SQRT(GARCH(-1))) + C(4)*ABS(RESID(-2)/ @SQRT(GARCH(-2))) + C(5)*RESID(-1)/@SQRT(GARCH(-1)) + C(6)*LOG(GARCH(-1)) + C(7)*LOG(GARCH(-2)) + C(8)*DD

Variable	Coefficient	Std. Error	z-Statistic	Prob.
Mean Equation				
DD	0.66333**	0.326686	2.03048	0.0423
C	0.827178**	0.397997	2.078353	0.0377
Variance Equation				
C(2)	0.23061*	0.02498	9.23179	0
C(3)	0.0623*	0.02124	2.9337	0.0033
C(4)	0.05668*	0.0195	2.90731	0.0036
C(5)	0.17304*	0.01522	11.3715	0
C(6)	0.11424*	0.00933	12.2399	0
C(7)	0.14133*	0.00785	18.0036	0
C(8)	0.15699*	0.04782	3.28316	0

***significant at 1%, **significant at 5%, ***significant at 10%**
DD is the dummy for dara variety

Table-4.17: Results of ARCH/GARCH Estimation In Case UP Under Wheat

LOG(GARCH) = C(3) + C(4)*ABS(RESID(-1)/@SQRT(GARCH(-1))) + C(5)*RESID(-1)/@SQRT(GARCH(-1)) + C(6)*LOG(GARCH(-1)) + C(7)*DI +C(8)*DW

Variable	Coefficient	Std. Error	z-Statistic	Prob.
Mean Equation				
DI	0.14638*	0.03893	3.75991	0
DW	0.10031*	0.01164	8.62166	0
C	0.978665*	0.251313	3.894203	0.0001
Variance Equation				
C(3)	0.05044*	0.01026	4.91483	0
C(4)	0.20224*	0.00931	21.7135	0
C(5)	0.06621*	0.01947	3.4002	0
C(6)	0.22179*	0.02755	8.05053	0
C(7)	0.09116*	0.01446	6.3058	0
C(8)	0.15273*	0.01233	12.3905	0

***significant at 1%, **significant at 5%, ***significant at 10%**
DI and DW are the dummies for imported and white variety

Table-4.18: Results of Unit Root Test for Each States In Case of Jowar

	ADF	P-VALUE	PP	P-VALUE	KPSS
AP	-24.0692*	0	-24.0424*	0	0.022481*
GU	-24.328*	0	-24.3874*	0	0.024689*
KA	-23.7656*	0	-23.7767*	0	0.023279*
TN	-23.7867*	0	-42.223*	0.0001	0.094826*
UP	-17.6999*	0	-25.4528*	0	0.022051*

***significant at 1%, **significant at 5%, ***significant at 10%**

Table-4.19: Results of ARCH Effect for Each States In Case of Jowar

STATES	CHI-SQUARED VALUE	P-VALUE
AP	2.103449	0.83465367
GU	19.047634*	0.00188326
KA	0.856192	0.97331165
TN	209.990722*	0
UP	23.048479*	0.00033044

***significant at 1%, **significant at 5%, ***significant at 10%**

Table-4.20: Results of ARCH/GARCH Estimation In Case GU Under Jowar

LOG(GARCH) = C(2) + C(3)*ABS(RESID(-1)/@SQRT(GARCH(-1))) + C(4)*RESID(-1)/@SQRT(GARCH(-1)) + C(5)*LOG(GARCH(-1)) + C(6)*LOG(GARCH(-2)) + C(7)*DY

Variable	Coefficient	Std. Error	z-Statistic	Prob.
Mean Equation				
DY	0.7953*	0.243279	3.26907	0.0011
C	0.811052	0.551002	1.471959	0.141
Variance Equation				
C(2)	0.141628*	0.018838	7.5182079	0
C(3)	0.1250857*	0.027122	4.6119645	0
C(4)	0.164036*	0.028978	5.6607081	0
C(5)	0.113183*	0.023123	4.8948233	0
C(6)	0.134985*	0.018193	7.4196119	0
C(7)	0.04406*	0.012089	3.6446356	0

***significant at 1%, **significant at 5%, ***significant at 10%**
DY is the dummy for yellow variety

Table-4.21: Results of ARCH/GARCH Estimation In Case TN Under Jowar

LOG(GARCH) = C(2) + C(3)*ABS(RESID(-1)/@SQRT(GARCH(-1))) + C(4)*RESID(-1)/@SQRT(GARCH(-1)) + C(5)*LOG(GARCH(-1)) + C(6)*LOG(GARCH(-2)) + C(7)*DR

Variable	Coefficient	Std. Error	z-Statistic	Prob.
Mean Equation				
DR	0.340892*	0.091798	3.7135014	0
C	0.713283*	0.242681	2.939177	0.0033
Variance Equation				
C(2)	0.109275*	0.016724	6.534023	0
C(3)	0.242657*	0.067978	3.5696402	0
C(4)	0.05493*	0.0126	4.3595238	0
C(5)	0.163662*	0.02735	5.9839854	0
C(6)	0.140382*	0.02602	5.3951576	0
C(7)	0.22985*	0.03957	5.8086935	0

***significant at 1%, **significant at 5%, ***significant at 10%**
DR is the dummy for red variety

Table-4.22: Results of ARCH/GARCH Estimation In Case UP Under Jowar

LOG(GARCH) = C(2) + C(3)*ABS(RESID(-1)/@SQRT(GARCH(-1))) + C(4)*ABS(RESID(-2)/@SQRT(GARCH(-2))) + C(5)*RESID(-1)/@SQRT(GARCH(-1)) + C(6)*LOG(GARCH(-1)) + C(7)*DW

Variable	Coefficient	Std. Error	z-Statistic	Prob.
Mean Equation				
DW	0.832508*	0.213942	3.891279	0
C	0.36343*	0.026035	13.95941	0
Variance Equation				
C(2)	0.120835**	0.057901	2.0869242	0.0369
C(3)	0.298686*	0.059507	5.0193423	0
C(4)	0.044991*	0.006098	7.3779928	0
C(5)	0.060449*	0.005227	11.56476	0
C(6)	0.219967*	0.031901	6.8953011	0
C(7)	0.196724*	0.03846	5.1150286	0

***significant at 1%, **significant at 5%, ***significant at 10%**
DW is the dummy for white variety

Table-4.23: Results of Unit Root Test for Each States In Case of Bajra

	ADF	P-VALUE	PP	P-VALUE	KPSS
AP	-26.9779*	0	-28.8337*	0	0.03092*
GU	-24.2863*	0	-24.2174*	0	0.016152*
HA	-23.744*	0	-23.7447*	0	0.03698*
KA	-19.1306*	0	-50.5327*	0.0001	0.034068*
MA	-18.2448*	0	-42.1639*	0.0001	0.028804*
RA	-23.724*	0	-23.7232*	0	0.019773*
TN	-22.9602*	0	-44.2834*	0.0001	0.024153*
UP	-21.5821*	0	-33.4096*	0	0.023472*

***significant at 1%, **significant at 5%, ***significant at 10%**

Table-4.24: Results of ARCH Effect for Each States In Case of Bajra

STATES	CHI-SQUARED VALUE	P-VALUE
AP	25.544119*	0.00010936
GU	4.623085	0.46358578
HA	24.208307*	0.00019799
KA	214.495257*	0
MA	212.042623*	0
RA	14.147428*	0.01469956
TN	215.216259*	0
UP	174.860309*	0

***significant at 1%, **significant at 5%, ***significant at 10%**

Table-4.25: Results of ARCH/GARCH Estimation In Case AP Under Bajra

LOG(GARCH) = C(2) + C(3)*ABS(RESID(-1)/@SQRT(GARCH(-1))) + C(4)*RESID(-1)/@SQRT(GARCH(-1)) + C(5)*LOG(GARCH(-1)) + C(6)*DL

Variable	Coefficient	Std. Error	z-Statistic	Prob.
Mean Equation				
DL	0.695254*	0.192366	3.614224	0.0003
C	0.894718*	0.281394	3.179595	0.0015
Variance Equation				
C(2)	0.108354*	0.043478	2.492157	0.0127
C(3)	0.211337*	0.039274	5.3810918	0
C(4)	0.058314*	0.026592	2.1929152	0.0283
C(5)	0.219228*	0.020459	10.71548	0
C(6)	0.034776*	0.012995	2.6761062	0.0134

***significant at 1%, **significant at 5%, ***significant at 10%**
DL is the dummy for local variety

Table-4.26: Results of ARCH/GARCH Estimation In Case HA Under Bajra

LOG(GARCH) = C(3) + C(4)*ABS(RESID(-1)/@SQRT(GARCH(-1))) + C(5)*RESID(-1)/@SQRT(GARCH(-1)) + C(6)*LOG(GARCH(-1)) + C(7)*DC +C(8)*DD

Variable	Coefficient	Std. Error	z-Statistic	Prob.
Mean Equation				
DC	0.44458*2	0.083934	5.2968046	0
DD	0.83695*9	0.218512	3.8302656	0.0001
C	0.379335*	0.043598	8.700662	0
Variance Equation				
C(3)	0.250082*	0.048069	5.202563	0
C(4)	0.136688*	0.031007	4.4082949	0
C(5)	0.06892***	0.04146	1.6623251	0.0964
C(6)	0.103589*	0.018914	5.4768426	0
C(7)	0.187844*	0.033191	5.659486	0
C(8)	0.212614*	0.051772	4.1067372	0

***significant at 1%, **significant at 5%, ***significant at 10%**
DC and DD are the dummies for coarse and desi variety

Table-4.27: Results of ARCH/GARCH Estimation In Case KA Under Bajra

LOG(GARCH) = C(2) + C(3)*ABS(RESID(-1)/@SQRT(GARCH(-1))) + C(4)*ABS(RESID(-2)/@SQRT(GARCH(-2))) + C(5)*RESID(-1)/@SQRT(GARCH(-1)) + C(6)*LOG(GARCH(-1)) + C(7)*DS

Variable	Coefficient	Std. Error	z-Statistic	Prob.
Mean Equation				
DS	0.076473*	0.009077	8.424661	0
C	0.965515	0.875588	1.102705	0.2702
Variance Equation				
C(2)	0.047806*	0.014613	3.2714706	0.0011
C(3)	0.184902*	0.033928	5.4498349	0
C(4)	0.230865*	0.046289	4.98747	0
C(5)	0.254506*	0.020928	12.161028	0
C(6)	0.097091*	0.003256	29.819103	0
C(7)	0.135302*	0.008203	16.494209	0

***significant at 1%, **significant at 5%, ***significant at 10%**
DS is the dummy for superior variety

Table-4.28: Results of ARCH/GARCH Estimation In Case MA Under Bajra

LOG(GARCH) = C(1) + C(2)*ABS(RESID(-1)/@SQRT(GARCH(-1))) + C(3)*ABS(RESID(-2)/@SQRT(GARCH(-2))) + C(4)*RESID(-1)/@SQRT(GARCH(-1)) + C(5)*LOG(GARCH(-1)) + C(6)*LOG(GARCH(-2))

Variable	Coefficient	Std. Error	z-Statistic	Prob.
Variance Equation				
C(1)	0.190205*	0.033472	5.6825108	0
C(2)	0.196166*	0.043119	4.5494098	0
C(3)	0.054253*	0.012302	4.4100959	0
C(4)	0.038506*	0.01128	3.4136525	0
C(5)	0.161748*	0.045793	3.5321556	0
C(6)	0.16278*	0.021115	7.7092115	0
C(1)	0.130205*	0.013472	9.6648605	0

***significant at 1%, **significant at 5%, ***significant at 10%**

Table-4.29: Results of ARCH/GARCH Estimation In Case RA Under Bajra

LOG(GARCH) = C(3) + C(4)*ABS(RESID(-1)/@SQRT(GARCH(-1))) + C(5)*RESID(-1)/@SQRT(GARCH(-1)) + C(6)*LOG(GARCH(-1)) + C(7)*LOG(GARCH(-2)) + C(8)*DL + C(9)*DS

Variable	Coefficient	Std. Error	z-Statistic	Prob.
Mean Equation				
DL	0.073686*	0.01876	3.927825	0
DS	0.427583*	0.112345	3.805982	0
C	0.494379	0.607476	0.813824	0.4157
Variance Equation				
C(3)	0.184821*	0.052843	3.4975493	0.0021
C(4)	0.118427*	0.028185	4.201774	0
C(5)	0.088091*	0.018394	4.789116	0
C(6)	0.102472*	0.063215	1.6210077	0.105
C(7)	0.171182*	0.042976	3.9831999	0
C(8)	0.099048*	0.017158	5.7727008	0
C(9)	0.109834*	0.012266	8.9543453	0

***significant at 1%, **significant at 5%, ***significant at 10%**
DL and DS are the dummies for local and small variety

Table-4.30: Results of ARCH/GARCH Estimation In Case TN Under Bajra

LOG(GARCH) = C(2) + C(3)*ABS(RESID(-1)/@SQRT(GARCH(-1))) + C(4)*RESID(-1)/@SQRT(GARCH(-1)) + C(5)*LOG(GARCH(-1)) + C(6)*DL

Variable	Coefficient	Std. Error	z-Statistic	Prob.
Mean Equation				
DL	0.188768*	0.044749	4.2183736	0
C	0.322579*	0.121127	2.663144	0.0077
Variance Equation				
C(2)	0.167414*	0.039545	4.2335061	0
C(3)	0.264418*	0.06317	4.1858161	0
C(4)	0.158762*	0.046856	3.3882961	0
C(5)	0.073189*	0.007325	9.9916724	0
C(6)	0.158197*	0.025891	6.1101155	0

***significant at 1%, **significant at 5%, ***significant at 10%**
DL is the dummy for local variety

Table-4.31: Results of ARCH/GARCH Estimation In Case UP Under Bajra

LOG(GARCH) = C(3) + C(4)*ABS(RESID(-1)/@SQRT(GARCH(-1))) + C(5)*RESID(-1)/@SQRT(GARCH(-1)) + C(6)*LOG(GARCH(-1)) + C(7)*DL +C(8)*DF

Variable	Coefficient	Std. Error	z-Statistic	Prob.
Mean Equation				
DL	0.119611*	0.029608	4.03982	0
DF	0.04220*	0.005994	7.040456	0
C	0.02757	0.427424	0.064503	0.9486
Variance Equation				
C(3)	0.184314*	0.0500599	3.6818691	0
C(4)	0.280797*	0.063053	4.4533488	0
C(5)	0.058779*	0.008494	6.9200612	0
C(6)	0.166264*	0.022739	7.3118431	0
C(7)	0.142207*	0.039718	3.5804169	0
C(8)	0.138608*	0.012306	11.263449	0

***significant at 1%, **significant at 5%, ***significant at 10%**
DL and DF are the dummies for local and FAQ variety

Table-4.32: Results of Unit Root Test for Each States In Case of Maize

	ADF	P-VALUE	PP	P-VALUE	KPSS
AP	-23.3283*	0	-25.8979*	0	0.027671*
BI	-20.2805*	0	-20.2708*	0	0.033349*
GU	-23.7286*	0	-23.8105*	0	0.015396*
HP	-22.9018*	0	-22.8461*	0	0.016487*
KA	-22.0253*	0	-23.4531*	0	0.032946*
MP	-22.9162*	0	-41.1576*	0	0.030221*
PU	-24.249*	0	-24.7367*	0	0.01371*
RA	-23.3955*	0	-23.3955*	0	0.021556*
UP	-19.456*	0	-46.5222*	0.0001	0.046914*

***significant at 1%, **significant at 5%, ***significant at 10%**

Table-4.33: Results of ARCH Effect for Each States In Case of Maize

STATES	CHI-SQUARED VALUE	P-VALUE
AP	6.359428	0.27279876
BI	6.893749	0.22866302
GU	10.877971***	0.05385386
HP	12.435238**	0.02928698
KA	8.953019	0.1109528
MP	211.761832*	0
PU	9.37136***	0.09513759
RA	11.844143**	0.03698693
UP	193.663515*	0

***significant at 1%, **significant at 5%, ***significant at 10%**

Table-4.34: Results of ARCH/GARCH Estimation In Case GU Under Maize

LOG(GARCH) = C(2) + C(3)*ABS(RESID(-1)/@SQRT(GARCH(-1))) + C(4)*ABS(RESID(-2)/@SQRT(GARCH(-2))) + C(5)*RESID(-1)/@SQRT(GARCH(-1)) + C(6)*LOG(GARCH(-1)) + C(7)*DY

Variable	Coefficient	Std. Error	z-Statistic	Prob.
Mean Equation				
DY	0.566198**	0.25361	2.232553	0.0256
C	0.965907*	0.151001	6.396706	0
Variance Equation				
C(2)	0.170994	0.104401	1.6378579	0.1015
C(3)	0.156332*	0.031166	5.0161073	0
C(4)	0.118616*	0.012554	9.4484626	0
C(5)	0.108353**	0.049146	2.2047166	0.0275
C(6)	0.139669*	0.031561	4.4253668	0
C(7)	0.239374*	0.058014	4.126142	0

***significant at 1%, **significant at 5%, ***significant at 10%**
DY is the dummy for yellow variety

Table-4.35: Results of ARCH/GARCH Estimation In Case HP Under Maize

GARCH = C(1) + C(2)*RESID(-1)^2 + C(3)*RESID(-2)^2 + C(4)*GARCH(-1)+ C(5)*GARCH(-2)

Variable	Coefficient	Std. Error	z-Statistic	Prob.
Variance Equation				
C(1)	0.43347*	0.0572374	7.5731951	0
C(2)	0.106441*	0.020435	5.2087595	0
C(3)	0.208964*	0.087882	2.3777793	0.0174
C(4)	0.108639*	0.017793	6.1057157	0
C(5)	0.107323*	0.031493	3.4078367	0

***significant at 1%, **significant at 5%, ***significant at 10%**

Table-4.36: Results of ARCH/GARCH Estimation In Case MP Under Maize

LOG(GARCH) = C(2) + C(3)*ABS(RESID(-1)/@SQRT(GARCH(-1))) + C(4)*RESID(-1)/@SQRT(GARCH(-1)) + C(5)*LOG(GARCH(-1)) + C(6)*DW

Variable	Coefficient	Std. Error	z-Statistic	Prob.
Mean Equation				
DW	0.616171*	0.133148	4.627715	0
C	0.363649	0.393663	0.923758	0.3556
Variance Equation				
C(2)	0.046862*	0.0104044	4.504056	0
C(3)	0.119392*	0.015074	7.9203927	0
C(4)	0.19327*	0.04748	4.070556	0
C(5)	0.256569*	0.070459	3.6413943	0.0003
C(6)	0.154522*	0.01425	10.843649	0

***significant at 1%, **significant at 5%, ***significant at 10%**
DW is the dummy for white variety

Table-4.37: Results of ARCH/GARCH Estimation In Case PU Under Maize

LOG(GARCH) = C(2) + C(3)*ABS(RESID(-1)/@SQRT(GARCH(-1))) + C(4)*RESID(-1)/@SQRT(GARCH(-1)) + C(5)*LOG(GARCH(-1)) + C(6)*DC

Variable	Coefficient	Std. Error	z-Statistic	Prob.
Mean Equation				
DC	0.15306*	0.030427	5.030401	0
C	0.749097**	0.322492	2.322843	0.0202
Variance Equation				
C(2)	0.119869**	0.05377	2.229291	0.0258
C(3)	0.270526*	0.053632	5.044115	0
C(4)	0.147531*	0.034723	4.248798	0
C(5)	0.193353*	0.01501	12.88161	0
C(6)	0.093229*	0.021363	4.364041	0

***significant at 1%, **significant at 5%, ***significant at 10%**
DC is the dummy for coarse variety

Table-4.38: Results of ARCH/GARCH Estimation In Case RA Under Maize

LOG(GARCH) = C(4) + C(5)*ABS(RESID(-1)/@SQRT(GARCH(-1))) + C(6)*RESID(-1)/@SQRT(GARCH(-1)) + C(7)*LOG(GARCH(-1)) + C(8)*DL +C(9)*DR + C(10)*DC

Variable	Coefficient	Std. Error	z-Statistic	Prob.
Mean Equation				
DL	0.817122*	0.17594	4.644322	0
DR	0.403342*	0.103117	3.911499	0
DC	0.2535*	0.030103	8.421088	0
C	0.76626*	0.035141	21.80546	0
Variance Equation				
C(4)	0.12569	0.089261	1.4081178	0.1591
C(5)	0.158484*	0.024142	6.5646591	0
C(6)	0.052589*	0.013916	3.7790313	0
C(7)	0.200684*	0.027885	7.1968442	0
C(8)	0.133199*	0.021721	6.1322683	0
C(9)	0.196066*	0.017124	11.449778	0
C(10)	0.338931*	0.066404	5.1040751	0

***significant at 1%, **significant at 5%, ***significant at 10%**
DL, DR and DC are the dummies for Local, Red and Coarse variety

Table-4.39: Results of ARCH/GARCH Estimation In Case UP Under Maize

GARCH = C(1) + C(2)*RESID(-1)^2 + C(3)*RESID(-2)^2 + C(4)*GARCH(-1)+ C(5)*GARCH(-2)

Variable	Coefficient	Std. Error	z-Statistic	Prob.
Variance Equation				
C	0.1019*	0.01838	5.5440696	0
C(2)	0.329577*	0.079048	4.1693275	0
C(3)	0.133247*	0.013641	9.7681255	0
C(4)	0.357607*	0.062417	5.7293205	0
C(5)	0.075758*	0.01137	6.6629727	0

***significant at 1%, **significant at 5%, ***significant at 10%**

Table-4.40: Results of Unit Root Test for Each States In Case of Gram

	ADF	P-VALUE	PP	P-VALUE	KPSS
BI	-18.9566*	0	-44.3235*	0.0001	0.053423*
MP	-24.9894*	0	-25.3031*	0	0.028964*
MA	-26.9984*	0	-27.2928*	0	0.016437*
PU	-23.0296*	0	-38.9332*	0	0.025693*
RA	-23.9152*	0	-23.8925*	0	0.022755*
UP	-23.0045*	0	-39.4424*	0	0.018906*

***significant at 1%, **significant at 5%, ***significant at 10%**

Table-4.41: Results of ARCH Effect for Each States In Case of Gram

STATES	CHI-SQUARED VALUE	P-VALUE
BI	207.785133*	0
MP	22.826039*	0.00036442
MA	11.092149**	0.04958325
PU	211.520284*	0
RA	18.336617*	0.00255281
UP	214.237286*	0

***significant at 1%, **significant at 5%, ***significant at 10%**

Table-4.42: Results of ARCH/GARCH Estimation In Case BI Under Gram

GARCH = C(1) + C(2)*RESID(-1)^2 + C(3)*RESID(-2)^2 + C(4)*GARCH(-1)+ C(5)*GARCH(-2)

Variable	Coefficient	Std. Error	z-Statistic	Prob.
Variance Equation				
C(1)	0.46909*	0.028268	16.5943	0
C(2)	0.143616*	0.025239	5.690233	0
C(3)	0.1459*	0.025463	5.729915	0
C(4)	0.0057*	0.001555	3.665595	0
C(5)	0.00716*	0.00249	2.875859	0.004

***significant at 1%, **significant at 5%, ***significant at 10%**

Table-4.43: Results of ARCH/GARCH Estimation In Case MP Under Gram

LOG(GARCH) = C(2) + C(3)*ABS(RESID(-1)/@SQRT(GARCH(-1))) + C(4)*RESID(-1)/@SQRT(GARCH(-1)) + C(5)*LOG(GARCH(-1)) + C(6)*DD

Variable	Coefficient	Std. Error	z-Statistic	Prob.
Mean Equation				
DD	0.25482*	0.015581	16.35411	0
C	0.15439	0.181939	0.84857	0.3961
Variance Equation				
C(2)	0.1882*	0.0184349	10.2089	0
C(3)	0.326963*	0.0168811	19.36864	0
C(4)	0.129559*	0.026104	4.963186	0
C(5)	0.058597*	0.003565	16.43675	0
C(6)	0.14238*	0.022139	6.431185	0

***significant at 1%, **significant at 5%, ***significant at 10%**
DD is the dummy for desi variety

Table-4.44: Results of ARCH/GARCH Estimation In Case MA Under Gram

LOG(GARCH) = C(1) + C(2)*ABS(RESID(-1)/@SQRT(GARCH(-1))) + C(3)*RESID(-1)/@SQRT(GARCH(-1)) + C(4)*LOG(GARCH(-1))

Variable	Coefficient	Std. Error	z-Statistic	Prob.
Variance Equation				
C(1)	0.440023*	0.108124	4.0696145	0
C(2)	0.172652*	0.031189	5.5356696	0
C(3)	0.130347*	0.032009	4.0721984	0
C(4)	0.174557*	0.027632	6.3172047	0

***significant at 1%, **significant at 5%, ***significant at 10%**

Table-4.45: Results of ARCH/GARCH Estimation In Case PU Under Gram

LOG(GARCH) = C(2) + C(3)*ABS(RESID(-1)/@SQRT(GARCH(-1))) + C(4)*ABS(RESID(-2)/@SQRT(GARCH(-2))) + C(5)*RESID(-1)/@SQRT(GARCH(-1)) + C(6)*LOG(GARCH(-1)) + C(7)*LOG(GARCH(-2)) + C(8)*DD

Variable	Coefficient	Std. Error	z-Statistic	Prob.
Mean Equation				
DD	0.587584*	0.146356	4.014759	0
C	0.223912*	0.083648	2.67685	0.0074
Variance Equation				
C(2)	0.170466*	0.025465	6.6941292	0
C(3)	0.111307*	0.026907	4.1367302	0
C(4)	0.088915*	0.01985	4.4793451	0
C(5)	0.070048*	0.01662	4.2146811	0
C(6)	0.118736*	0.017466	6.7981221	0
C(7)	0.150338*	0.029248	5.1401121	0
C(8)	0.106721*	0.014404	7.4091225	0

***significant at 1%, **significant at 5%, ***significant at 10%**
DD is the dummy for desi variety

Table-4.46: Results of ARCH/GARCH Estimation In Case RA Under Gram

LOG(GARCH) = C(2) + C(3)*ABS(RESID(-1)/@SQRT(GARCH(-1))) + C(4)*ABS(RESID(-2)/@SQRT(GARCH(-2))) + C(5)*RESID(-1)/@SQRT(GARCH(-1)) + C(6)*LOG(GARCH(-1)) + C(7)*LOG(GARCH(-2)) + C(8)*LOG(GARCH(-3)) + C(9)*DF

Variable	Coefficient	Std. Error	z-Statistic	Prob.
Mean Equation				
DF	0.403592*	0.156066	2.586031	0.0097
C	0.143992	0.146724	0.981377	0.3264
Variance Equation				
C(2)	0.007921**	0.003078	2.573424	0.0101
C(3)	0.1901*	0.031797	5.978551	0
C(4)	0.18752*	0.032675	5.738944	0
C(5)	0.023187*	0.003637	6.375309	0
C(6)	0.124567*	0.008602	14.48117	0
C(7)	0.117029*	0.016423	7.125921	0
C(8)	0.187879*	0.011563	16.24829	0
C(9)	0.012*	0.001994	6.018054	0

***significant at 1%, **significant at 5%, ***significant at 10%**
DF is the dummy for FAQ variety

Table-4.47: Results of ARCH/GARCH Estimation In Case UP Under Gram

GARCH = C(1) + C(2)*RESID(-1)^2 + C(3)*GARCH(-1) + C(4)*GARCH(-2)

Variable	Coefficient	Std. Error	z-Statistic	Prob.
Variance Equation				
C(1)	0.0457*	0.00257	17.7821	0
C(2)	0.308465***	0.183495	1.681054	0.0928
C(3)	0.395956*	0.151018	2.621913	0.0087
C(4)	0.091022***	0.051771	1.758166	0.0787

***significant at 1%, **significant at 5%, ***significant at 10%**

Table-4.48: Results of Unit Root Test for Each States In Case of Cotton

	ADF	P-VALUE	PP	P-VALUE	KPSS
AP	-8.68882*	0	-22.8763*	0	0.024318*
KA	-9.50115*	0	-24.5906*	0	0.032997*
PU	-10.5532*	0	-21.8627*	0	0.015737*

***significant at 1%, **significant at 5%, ***significant at 10%**

Table-4.49: Results of ARCH Effect for Each States In Case of Cotton

STATES	CHI-SQUARED VALUE	P-VALUE
AP	74.42544*	0
KA	114.039829*	0
PU	8.287517	0.14108571

***significant at 1%, **significant at 5%, ***significant at 10%**

Table-4.50: Results of ARCH/GARCH Estimation In Case AP Under Cotton

LOG(GARCH) = C(2) + C(3)*ABS(RESID(-1)/@SQRT(GARCH(-1))) + C(4)*RESID(-1)/@SQRT(GARCH(-1)) + C(5)*LOG(GARCH(-1)) + C(6)*DL

Variable	Coefficient	Std. Error	z-Statistic	Prob.
Mean Equation				
DL	0.216534*	0.0199	10.88111	0
C	0.196425*	0.02740	7.16847	0
Variance Equation				
C(2)	0.193292*	0.029881	6.4687259	0
C(3)	0.099762*	0.012636	7.8950617	0
C(4)	0.09497*	0.016139	5.8845034	0
C(5)	0.062329*	0.009786	6.3692009	0
C(6)	0.220302*	0.034234	6.4351814	0
C(2)	0.193292*	0.029881	6.4687259	0

***significant at 1%, **significant at 5%, ***significant at 10%**
DL is the dummy for laxmi variety

Table-4.51: Results of ARCH/GARCH Estimation In Case KA Under Cotton

LOG(GARCH) = C(2) + C(3)*ABS(RESID(-1)/@SQRT(GARCH(-1))) + C(4)*RESID(-1)/@SQRT(GARCH(-1)) + C(5)*LOG(GARCH(-1)) + C(6)*DL

Variable	Coefficient	Std. Error	z-Statistic	Prob.
Mean Equation				
DL	0.176954*	0.03306	5.352511	0
C	0.571381*	0.059762	9.560901	0
Variance Equation				
C(2)	0.302928*	0.058142	5.210141	0
C(3)	0.185015*	0.02249	8.226545	0
C(4)	0.200783*	0.0520993	3.853852	0
C(5)	0.175047*	0.0403307	4.340294	0
C(6)	0.10197*	0.0210294	4.848924	0

***significant at 1%, **significant at 5%, ***significant at 10%**
DL is the dummy for laxmi variety

Table-4.52: Results of Unit Root Test for Each States In Case of Groundnut

	ADF	P-VALUE	PP	P-VALUE	KPSS
AP	-23.1561*	0	-42.1404*	0.0001	0.049245*
GU	-24.7689*	0	-25.1085*	0	0.023754*
KA	-26.6177*	0	-27.7725*	0	0.136257**
MP	-21.8424*	0	-21.9369*	0	0.044104*
TN	-13.6924*	0	-21.2088*	0	0.037208*

***significant at 1%, **significant at 5%, ***significant at 10%**

Table-4.53: Results of ARCH Effect for Each States In Case of Groundnut

STATES	CHI-SQUARED VALUE	P-VALUE
AP	212.3525*	0
GU	16.93912*	0.004617
KA	11.22946**	0.047016
MP	8.206852	0.145198
TN	9.564132***	0.08857

***significant at 1%, **significant at 5%, ***significant at 10%**

Table-4.54: Results of ARCH/GARCH Estimation In Case AP Under Groundnut

LOG(GARCH) = C(2) + C(3)*ABS(RESID(-1)/@SQRT(GARCH(-1))) + C(4)*RESID(-1)/@SQRT(GARCH(-1)) + C(5)*LOG(GARCH(-1)) + C(6)*LOG(GARCH(-2)) + C(7)*DP

Variable	Coefficient	Std. Error	z-Statistic	Prob.
Mean Equation				
DP	0.178886*	0.021044	8.50057	0
C	0.351189	1.514287	0.231917	0.8166
Variance Equation				
C(2)	0.139284*	0.031162	4.469674	0
C(3)	0.053608*	0.009808	5.465742	0
C(4)	0.002471*	0.0007039	3.510442	0
C(5)	0.24337*	0.034251	7.105486	0
C(6)	0.257848*	0.026347	9.786617	0
C(7)	0.139412*	0.022623	6.162388	0

***significant at 1%, **significant at 5%, ***significant at 10%**
DP is the dummy for pods variety

Table-4.55: Results of ARCH/GARCH Estimation In Case GU Under Groundnut

LOG(GARCH) = C(2) + C(3)*ABS(RESID(-1)/@SQRT(GARCH(-1))) + C(4)*RESID(-1)/@SQRT(GARCH(-1)) + C(5)*LOG(GARCH(-1)) + C(6)*DS

Variable	Coefficient	Std. Error	z-Statistic	Prob.
Mean Equation				
DS	0.05514*	0.006456	8.540892	0
C	0.766269*	0.013604	56.32845	0
Variance Equation				
C(2)	0.27434*	0.0399914	6.85997	0
C(3)	0.244629*	0.0189231	12.92752	0
C(4)	0.115081*	0.026374	4.363426	0
C(5)	0.168742*	0.008317	20.28881	0
C(6)	0.11142*	0.020635	5.399564	0

***significant at 1%, **significant at 5%, ***significant at 10%**
DS is the dummy for shell variety

Table-4.56: Results of ARCH/GARCH Estimation In Case KA Under Groundnut

LOG(GARCH) = C(1) + C(2)*ABS(RESID(-1)/@SQRT(GARCH(-1))) + C(3)*ABS(RESID(-2)/@SQRT(GARCH(-2))) + C(4)*ABS(RESID(-3)/@SQRT(GARCH(-3))) + C(5)*RESID(-1)/@SQRT(GARCH(-1))

Variable	Coefficient	Std. Error	z-Statistic	Prob.
Variance Equation				
C(1)	0.1130324*	0.0110464	10.23253	0
C(2)	0.229754*	0.061041	3.763929	0
C(3)	0.160368*	0.0390406	4.107723	0
C(4)	0.252635*	0.073482	3.438053	0
C(5)	0.167533*	0.05246	3.193538	0.0014

***significant at 1%, **significant at 5%, ***significant at 10%**

Table-4.57: Results of ARCH/GARCH Estimation In Case TN Under Groundnut

GARCH = C(1) + C(2)*RESID(-1)^2 + C(3)*GARCH(-1)

Variable	Coefficient	Std. Error	z-Statistic	Prob.
Variance Equation				
C	0.481991**	0.2208092	2.182839	0.029
C(1)	0.158399*	0.029726	5.328635	0
C(2)	0.25427*	0.021789	11.66965	0

***significant at 1%, **significant at 5%, ***significant at 10%**

Table-4.58: Results of Unit Root Test for Each States In Case of Rapeseed/Mustard

	ADF	P-VALUE	PP	P-VALUE	KPSS
HA	-18.24*	0	-44.0193*	0.0001	0.05783*
UP	-26.2176*	0	-26.4146*	0	0.017145*
WB	-20.9652*	0	-20.8974*	0	0.02008*

***significant at 1%, **significant at 5%, ***significant at 10%**

Table-4.59: Results of ARCH Effect for Each States In Case of Rapeseed/Mustard

STATES	CHI-SQUARED VALUE	P-VALUE
HA	211.729281*	0
UP	93.571811*	0
WB	14.862133**	0.01096796

***significant at 1%, **significant at 5%, ***significant at 10%**

Table-4.60: Results of ARCH/GARCH Estimation In Case HA Under Rapeseed/Mustard

GARCH = C(1) + C(2)*RESID(-1)^2 + C(3)*RESID(-2)^2 + C(4)*GARCH(-1)+ C(5)*GARCH(-2)

Variable	Coefficient	Std. Error	z-Statistic	Prob.
Variance Equation				
C(1)	0.211857*	0.0240281	8.817057	0
C(2)	0.422446*	0.099897	4.228816	0
C(3)	0.039483*	0.007354	5.368915	0
C(4)	0.134231*	0.026275	5.108696	0
C(5)	0.136294*	0.012861	10.59747	0

***significant at 1%, **significant at 5%, ***significant at 10%**

Table-4.61: Results of ARCH/GARCH Estimation In Case UP Under Rapeseed/Mustard

LOG(GARCH) = C(3) + C(4)*ABS(RESID(-1)/@SQRT(GARCH(-1))) + C(5)*RESID(-1)/@SQRT(GARCH(-1)) + C(6)*LOG(GARCH(-1)) + C(7)*DL +C(8)*DLA

Variable	Coefficient	Std. Error	z-Statistic	Prob.
Mean Equation				
DL	0.804922*	0.10365	7.765769	0
DLA	0.374299*	0.049264	7.59782	0
C	0.43337	0.979663	0.44236	0.6582
Variance Equation				
C(3)	0.138856*	0.0243952	5.691944	0
C(4)	0.200191*	0.053174	3.764829	0
C(5)	0.153391*	0.046172	3.322165	0.0009
C(6)	0.168011*	0.027367	6.139182	0
C(7)	0.176385*	0.057287	3.078971	0.0021
C(8)	0.162229*	0.0245476	6.60876	0

***significant at 1%, **significant at 5%, ***significant at 10%**
DL and DLA are the dummies for Lahi and Laha

Table-4.62: Results of ARCH/GARCH Estimation In Case WB Under Rapeseed/Mustard

LOG(GARCH) = C(4) + C(5)*ABS(RESID(-1)/@SQRT(GARCH(-1))) + C(6)*ABS(RESID(-2)/@SQRT(GARCH(-2))) + C(7)*RESID(-1)/@SQRT(GARCH(-1)) + C(8)*LOG(GARCH(-1)) + C(9)*LOG(GARCH(-2)) + C(10)*DY + C(11)*DF + C(12)*DD

Variable	Coefficient	Std. Error	z-Statistic	Prob.
Mean Equation				
DY	0.262871*	0.071635	3.669589	0
DF	0.476658*	0.042889	11.11376	0
DD	0.804662*	0.164369	4.895461	0
C	0.65502	1.148885	0.57014	0.5686
Variance Equation				
C(4)	0.1639*	0.0280551	5.842079	0
C(5)	0.100314*	0.014539	6.899649	0
C(6)	0.072209*	0.017357	4.160224	0
C(7)	0.151925*	0.034184	4.444331	0
C(8)	0.069917*	0.012289	5.689397	0
C(9)	0.196259*	0.028613	6.859085	0
C(10)	0.079075*	0.0109	7.254587	0
C(11)	0.042982*	0.0059683	7.201672	0
C(12)	0.103552*	0.022721	4.557546	0

***significant at 1%, **significant at 5%, ***significant at 10%**
DY, DF and DD are the dummies for Yellow, Fresh and Desi

Chapter 5

Analysis of Total Factor Productivity Growth of Indian Agricultural Sector

5.1 Introduction

The productivity growth in agriculture is very important because it is not only the necessary condition but is also the sufficient condition for the advancement of the sector as well as the economy. In the literature, however, the term “productivity” is often misrepresented: it is used as synonyms to “labour productivity” in case of manufacturing sector, while used as synonyms to “yield productivity” in the case of Agriculture. But, the consideration of yield alone as a measure of productivity provides misleading indication of the degree of productivity improvement in agriculture (Coelli, 1996).

In the literature two concepts of productivity is often used, firstly, partial productivity which is define as the contribution of one factor/ input (say labour or capital) to output growth keeping the other factors constant. Secondly, Total Factor Productivity growth (TFPG) is a variable, which accounts for the growth of output which is not accounted for the in inputs and thus measures shift in output due to the shift in the production function over time, holding all inputs constant (Abramovitz, 1956; Denison, 1962, 1967, 1985; Hayami et al, 1979). It has been widely acknowledged in the economic literature that economic growth no matter how impressive is will not be sustainable without improvement in total factor productivity growth. Growth in total factor productivity in agriculture is both a necessary condition as well as sufficient condition for its development. It is a necessary condition because it enables agriculture to avoid the trap of Ricardo’s law of diminishing returns. It is sufficient condition because it increases production at a reduced unit cost in real terms (For example: Kahlon and Tyagi, 1983; Sidhu and Byarlee, 1992; Kumar and Mruthyunjaya, 1992; Rao, 1994; Kumar and Rosegrant, 1994; Sing, Pal and Moris, 1995; Acharya, 1998 etc.).TFP growth can be measured by **(i)** Growth Accounting Approach (GAA) [i.e. by constructing either Solow Index (Solow, 1957), or Kendrik Index (Kendrick, 1956, 1961, 1973) or Translog-Divisia Index (Solow, 1957; Jorgenson and Griliches, 1967; Christensen and Jorgenson, 1969, 1970)]. In the GAA, TFP is measured as the residual. **(ii)** Econometric (Parametric) Approach (i.e. by estimating production function or cost function).

The example of parametric method can be found in Kumbhakar et al (1999, 2000), Kumbhakar and Lovell (2000), among others. **(iii)** Non-parametric Approach (i.e. through Data Envelopment Analysis (DEA)). The most widely used measure of TFP growth is followed by constructing Malmquist Productivity Index (MPI). MPI scales output levels up or down radically with respect to the benchmark technology. Caves, Christensen and Diewert (1982) showed that for translog production function, Tornqvist output and indexes are equal to mean of two MPIs. They introduce MPI as ratio of output distance functions without any aggregation of inputs. Commonly the measurement of TFPG using MPI is done through Data Envelopment Analysis (DEA). DEA is a 'data-oriented' approach for evaluating the performance of multiple decision making units (DMUs). In DEA, TFPG is estimated by solving a mathematical programming problem given some assumptions on the production technology.

Since last six decades productivity growth in agriculture has been one of the focused areas of intense research. Both development economists and agricultural economists have tried to estimate the TFPG and also tried to find out the sources of productivity growth over time. Productivity growth in the agricultural sector is considered essential if agricultural sector output is to grow at a sufficiently rapid rate to meet the demands for food and raw materials arising out of steady population growth. There are not many studies on TFPG in agricultural sector in respect of developing countries. Most of these studies found a declining TFPG in the developing countries which may be unexpected and paradoxical results. Some of the studies relating to the estimation of agricultural TFPG in developing countries are as follows: Kawagoe et al. (1985), Kawagoe and Hayami (1985), Lau and Yotopoulos (1989), Fulginiti and Perrin (1993, 1998), Trueblood (1996) and Arnade (1998), Trueblood and Coggins (2003), Alauddin, Headey and Rao (2005), Coelli and Rao (2005), Restuccia et al. (2008), Belloumi and Matoussi (2009) and many others[1]. However, resent studies like Shahabinejad and Akbari (2010) found that during 1993 – 2007 total factor productivity has experienced a positive evolution in D-8 countries[2].

In case of India the measurement of TFPG in agriculture involves a number of studies like Kumar and Rosegrant (1994), Fan, Hazell and Thorat (1998), Murgai (1999), Forstner et al

[1] The details of each of the studies can be found in Chapter-2.
[2] For details see Chapter-2

(2002), Nin et al (2003), Bhushan (2005), Kumar and Mittal (2006), Bosworth and Collins (2008), Chand, Kumar and Kumar(2011) etc[3].

Most of the studies estimating TFPG in Indian agricultural sector adopt either growth accounting or econometric techniques. However, these methodologies implicitly assume that a firm is operating on its production frontier. Total factor productivity change, or the Solow residual thus obtained, is synonymous with the index of pure technical change. Such an interpretation rests on several restrictive assumptions, including constant returns to scale and marginal cost pricing (Hulten (2001)). Besides, the Solow residual is not pure technical change. It is a residual and can include scale effect and change in technical efficiency. The alternative measures can capture these other sources of productivity change but it is that they do not split them out. Decomposition of the change in productivity into its likely sources is important because it can identify the other factors responsible for productivity changes over time. Thus, along with estimating changes in productivity, this study also provides estimates of different components of total factor productivity change.

Departing from the common practice in the literature, some of the studies (like Trueblood (1996); Arnade (1998); Forstner et al (2002); Nin et al (2003); Bhushan (2005) among others) used the Malmquist Index of total factor productivity growth i.e. non-parametric method of Data Envelopment Analysis (DEA). The Malmquist Productivity Index, introduced by Caves, Christensen, and Diewert (1982) and operationalized by Färe, Grosskopf, Lindgren and Roos (1992) (FGLR) to measure productivity change, is a normative measure based on a reference technology underlying observed input output data. Färe et al. (1992) (FGLR) decomposed the Malmquist Productivity Index (MPI) into technical change (TC) and technical efficiency change (TEC) considering the constant return to scale (CRS) frontier as the benchmark. However, assumption of global constant return to scale is not always a meaningful assumption about the underlying technology, so the FGLR decomposition is not particularly meaningful when CRS does not hold. In their paper Färe, Grosskopf, Norris, and Zhang (1994) (FGNZ) re-modified and extended decomposition by considering variable returns to scale and isolate specific contributions of technical efficiency change (TEC), technical change (TC), and scale efficiency change (SEC) towards the overall productivity change. According to Ray and Desli (1997), this

[3] Details of these studies are presented in Chapter-2.

decomposition raises a problem of internal consistency because it uses CRS and variable returns to scale (VRS) within the same decomposition. They provide a modified decomposition by using the variable returns to scale frontier as a benchmark. In that decomposition, scale efficiency change is obtained by considering both the constant returns to scale technology and the variable returns to scale technology. However, when one estimate cross-period efficiency scores (which is measured by comparing actual output of a firm in period *t* with the maximum producible output from period *t* +1 input set) under a VRS technology, it may result in linear programming infeasibilities for some observations.

In 2011, Pastor, Asmild and Lovell provides a new Malmquist Index which is known as the Biennial Malmquist Index (BMI) which used the same decomposition as provided by Ray and Desli but it solved the infeasibility problem associated with the Ray-Desli decomposition of the Malmquist Index. Instead of using a contemporaneous production possibility frontier, they estimated the technical efficiency of a production unit with reference to a biennial production possibility frontier.

Given this background, the **objectives** of the present chapter are **first of all** to find out the TFPG of Indian agricultural sector by using Biennial Malmquist Index (BMI) of non-parametric method of Data Envelopment Analysis (DEA). This study tried to find out TFPG for some selected crops of the Indian agricultural sector. Under each selected crops major producing states are considered as the multiple decision making units (DMUs). After finding out the extent of TFPG, the **second objective** is to decompose TFPG into its different components: technical changes, efficiency changes and scale efficiency changes to check which component dominates over the other while finding out the major sources of TFPG. **Thirdly**, this chapter tries to explain the factors behind the variation in TFPG.

Rest of the chapter is as follows:

Section 5.2 discusses the methodology and data source. In **subsection 5.2.1** the methodology for measuring Biennial Malmquist Index (BMI) of non-parametric method of Data Envelopment Analysis (DEA) is discussed. In **subsection 5.2.1** methodology for finding out determinants explaining variation in TFPG by using simultaneous panel regression approach has been discussed. Data Sources are discussed in **5.2.3**. **Section 5.3** presents the results of estimation elaborately and some concluding remarks are made in **Section 5.4.**

5.2 Methodology and Data Source

5.2.1 Methodology of measuring Biennial Malmquist Index (BMI)

Analysis of productivity change can use either a parametric method or the non-parametric index number approach. Theoretically productivity of a firm is measured by the quantity of output produced per unit of input. In the single input, single output case it is simply the average productivity of the input - measured as a ratio of the firm's output and input quantities - is easy to compute. In most situations, however, we encounter multiple inputs and outputs, in which case some economically meaningful aggregation of inputs and outputs is necessary. That is when multiple inputs and/or multiple outputs are involved, one must replace the simple ratios of the output and input quantities by ratio of quantity indices of output and input (see Ray (2004, p. 279-295) for details).Further Total factor productivity change can be decomposed into three factors showing technical change, efficiency change and returns to scale effects. The parametric approach – primal or dual – involves an explicit specification of the production or cost function, which is then estimated by appropriate econometric techniques (see Denny, Fuss, and Waverman (1981), Nishimizu and Page (1982), and Bauer (1990) for details) to measure and decompose the productivity change of a production unit.

In this chapter we adopt the non-parametric (primal) approach to measure total factor productivity change. In the non-parametric approach, productivity index is used to measure productivity change.

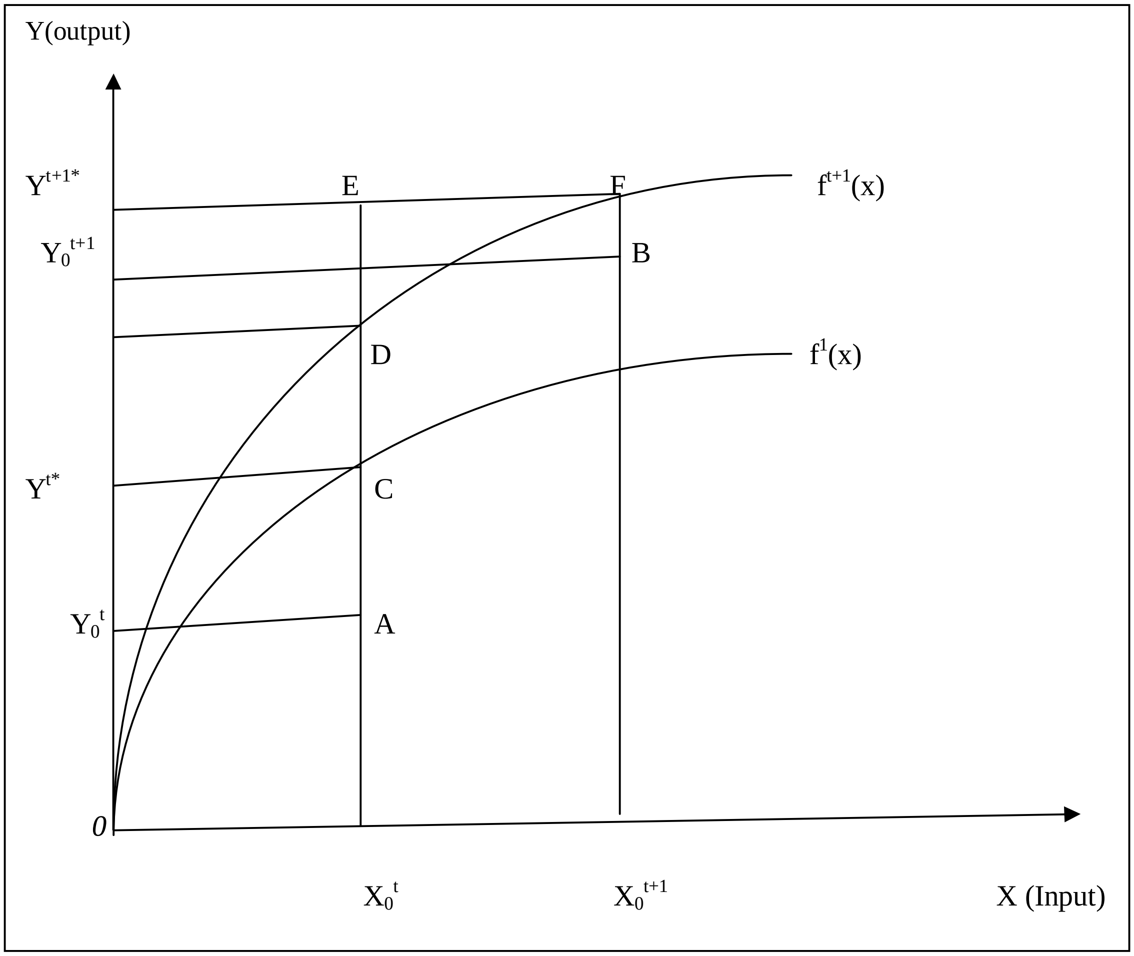


Figure 1: Decomposition of Productivity Index

Figure 1 illustrates the measurement of productivity index and decomposition of it into above mentioned three components for a single input-single output case.

If in period t a firm produces output Y_0^t (Point A) from input X_0^t its productivity is

$$\pi_t = \frac{Y_0^t}{X_0^t} = \left(\frac{AX_0^t}{OX_0^t}\right) \qquad \text{...5.1}$$

Similarly, in period t+1, when output Y_0^{t+1} (Point B) is produced from input X_0^{t+1}, the productivity is

$$\pi_{t+1} = \frac{Y_0^{t+1}}{X_0^{t+1}} = \left(\frac{BX_0^{t+1}}{OX_0^{t+1}}\right) \quad \text{...5.2}$$

The productivity change in the period t+1, with period t as the base is measured by

$$\pi_{t+1|t} = \frac{\pi_{t+1}}{\pi_t} = \frac{\left(\frac{BX_0^{t+1}}{OX_0^{t+1}}\right)}{\left(\frac{AX_0^{t}}{OX_0^{t}}\right)} \quad \text{...5.3}$$

Now suppose that the production function is $Y^{t*} = f^t(X^t)$ in period t and $Y^{t+1*} = f^{t+1}(X^{t+1})$ in period t+1. Because each observed input-output bundle is by definition feasible in the relevant period, $f^t(X^t) \geq Y_0^t$ and $f^{t+1}(X^{t+1}) \geq Y_0^{t+1}$. Thus the productivity index, as defined in (5.3), can be rewritten and decomposed as

$$\pi_{t+1|t} = \frac{\pi_{t+1}}{\pi_t} = \frac{\left(\frac{BX_0^{t+1}}{OX_0^{t+1}}\right)}{\left(\frac{AX_0^{t}}{OX_0^{t}}\right)}$$

$$= \frac{\left(\frac{BX_0^{t+1}}{FX_0^{t+1}}\right)}{\left(\frac{AX_0^{t}}{CX_0^{t}}\right)} X \frac{\left(\frac{FX_0^{t+1}}{OX_0^{t+1}}\right)}{\left(\frac{CX_0^{t}}{OX_0^{t}}\right)}$$

$$= \frac{\left(\frac{BX_0^{t+1}}{FX_0^{t+1}}\right)}{\left(\frac{AX_0^{t}}{CX_0^{t}}\right)} \left(\frac{DX_0^{t}}{CX_0^{t}}\right) \frac{\left(\frac{FX_0^{t+1}}{OX_0^{t+1}}\right)}{\left(\frac{DX_0^{t}}{OX_0^{t}}\right)}$$

$$= \left[\frac{\frac{Y_0^{t+1}}{f^{t+1}(X^{t+1})}}{\frac{Y_0^{t}}{f^{t}(X^{t})}}\right] X \left[\frac{f^{t+1}(X^t)}{f^t(X^t)}\right] X \left[\frac{\frac{f^{t+1}(X^{t+1})}{X^{t+1}}}{\frac{f^{t+1}(X^{t})}{X^{t}}}\right]$$

=TEC *X* TC *X* SEC ...5.4

The first component in this expression (*TEC*) is the ratio of the technical efficiencies of the firm in two periods and captures the contribution of technical efficiency change over time. The second term (*TC*) shows how the maximum producible output from input X_0^t changes between period t and t +1 and captures the autonomous shift in the production function due to technical change. Finally the last term (*SEC*) identifies the returns to scale effect over time.

Non Parametric Estimation of Productivity Index

This study considers the non-parametric method of Data Envelopment Analysis (DEA) introduced by Charnes, Cooper and Rhodes (1978) (CCR) and further generalized for variable returns to scale technology by Banker, Charnes and Cooper (1984) (BCC) in order to measure and decompose the Malmquist index of total factor productivity.

The major advantage of using DEA is that, unlike in the parametric approach, there is no need to specify any explicit functional form for the production function (e.g., Cobb-Douglas or Translog) and mathematical programming techniques can be used to get point-wise estimates of the production function. In fact, DEA allows one to construct the production possibility set from observed input-output bundles on the basis of the following four assumptions:

a) All observed input-output combinations are feasible;
b) The production possibility set is convex;
c) Inputs are freely disposable; and
d) Outputs are freely disposable.

Now, consider an industry producing one output y^t from one input x^t in period *t*. The input output bundle (x^t , y^t) is considered as feasible if the output y^t can be produced from the input x^t . Let (x_j^t, y_j^t) represent the input-output bundle of firm j ; and suppose that input-output data are observed for *n* firms. Then, based on the above assumptions, in period *t*, the production possibility set showing a variable returns to scale (VRS) technology is

$$\boldsymbol{T_v^t} = \left\{(\boldsymbol{x}, \boldsymbol{y}): \boldsymbol{x} \geq \sum_{\boldsymbol{j=1}}^{\boldsymbol{n}} \boldsymbol{\lambda_j}\, x_j^t; y \leq \sum_{j=1}^{n} \lambda_j\, y_j^t; \sum_{j=1}^{n} \lambda_j = 1; \lambda_j \geq 0; (j = 1,2,3, \dots n)\right\}$$

Under the constant returns to scale (CRS) assumption, if any (*x*, *y*) is feasible, so is the bundle (*kx*,*ky*) for any *k* > 0 . The production possibility set then becomes

$$\boldsymbol{T_c^t} = \left\{ (\boldsymbol{x}, \boldsymbol{y}) : \boldsymbol{x} \geq \sum_{\boldsymbol{j=1}}^{\boldsymbol{n}} \boldsymbol{\lambda_j} \, x_j^t ; y \leq \sum_{j=1}^{n} \lambda_j \, y_j^t ; \lambda_j \geq 0; (j = 1,2,3, \dots n) \right\}$$

One can measure the output-oriented technical efficiency $TE^t(x_s^t, y_s^t)$ of a firm *s* in period *t* by comparing its actual output $y_s^t$with the maximum producible quantity from its observed input x_s^t. Therefore, the output-oriented technical efficiency of firm *s* in period *t* is

$TE^t(x_s^t, y_s^t) = \frac{1}{\theta_s^*}$; where $\theta_s^* = max \;\; \theta : (x_s^t, \theta y_s^t) \in T^t$ and $T^t$is the period t production possibility set.

An alternative characterization of technical efficiency in terms of the Shephard Distance Function is $D^t(x_s^t, y_s^t) = \min \lambda : \left(x_s^t, \frac{1}{\lambda} y_s^t \right) \in T^t$. It can be seen that $\lambda = \frac{1}{\theta_s^*}$

Caves et al. (1982) defined the Malmquist Productivity Index as the ratio of the period *t* and period *t* +1 output-oriented Shephard distance functions pertaining to a certain benchmark technology. Equivalently, the Malmquist Index of total factor productivity of the firm *s* is

$$\boldsymbol{M_c}(x_s^t, y_s^t;\, x_s^{t+1}, y_s^{t+1}) = \left[\frac{TE_c^{t+1}(x_s^{t+1}, y_s^{t+1})}{TE_c^{t+1}(x_s^t, y_s^t)} \frac{TE_c^t(x_s^{t+1}, y_s^{t+1})}{TE_c^t(x_s^t, y_s^t)} \right]^{\frac{1}{2}} \qquad \dots 5.5$$

The standard non-parametric DEA model used to estimate the period *t* output-oriented technical efficiency of a firm *s*, relative to contemporaneous CRS frontier is

$\theta_s^* = max \; \theta$

Subject to $\sum_{j=1}^{n} \lambda_j \, y_j^t \geq \theta y_s^t$;

$\sum_{j=1}^{n} \lambda_j \, x_j^t \leq x_s^t$;

$\lambda_j \geq 0; (j = 1,2,3, \dots n)$;

And $TE^t(x_s^t, y_s^t) = \frac{1}{\theta_s^*}$

By imposing the additional restriction $\sum_{j=1}^{n} \lambda_j = 1$ in this DEA model, period t out-put oriented technical efficiency under VRS technology of a firm s can be estimated as $TE_v^t(x_s^t, y_s^t)$.

It has been already mentioned that the Biennial Malmquist Index introduced by Pastor, Asmild, and Lovell (2011) provides the same decomposition and avoids the infeasibility problem associated with the Ray-Desli decomposition of the Malmquist Index.

Instead of using a contemporaneous production possibility frontier, they estimated the technical efficiency of a production unit with reference to a biennial production possibility frontier. So in order to understand the Biennial Malmquist Index one has to first construct the Biennial Production Possibility Frontier.

Simple Graphical illustration of Biennial Production Possibility Frontier

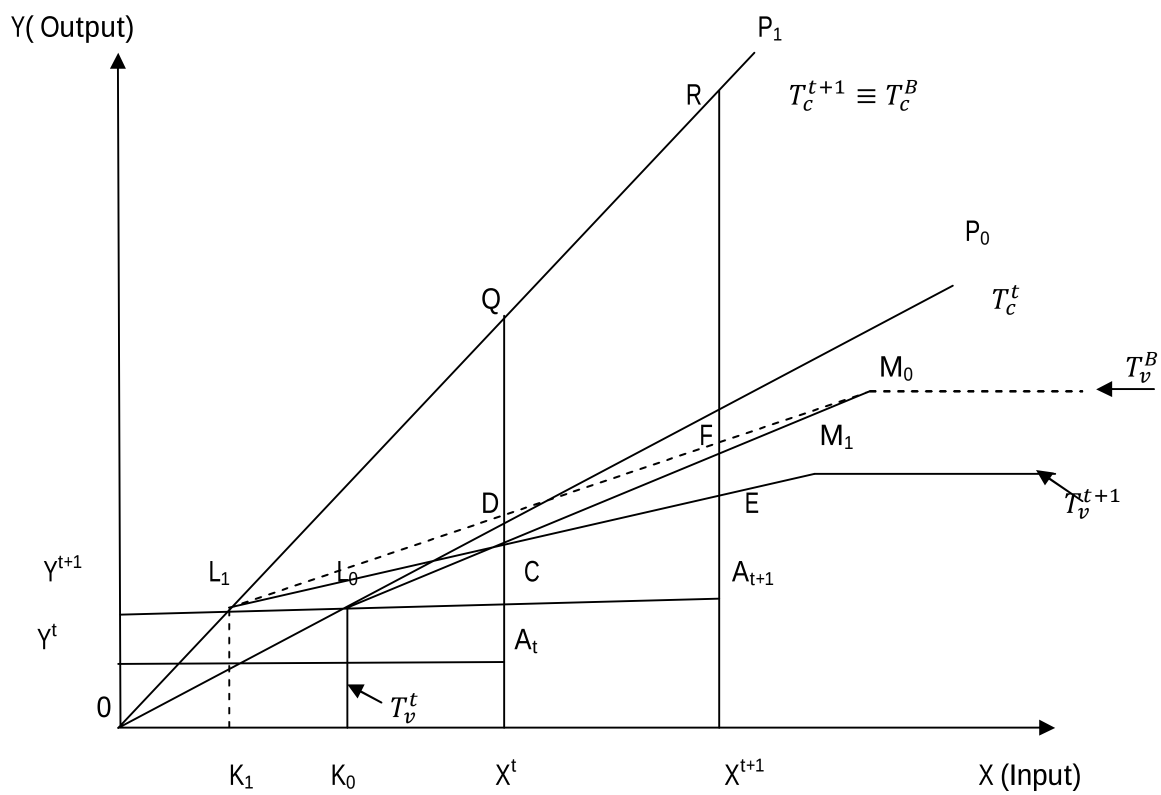


Figure2: Biennial Production Possibility Frontier

Figure 2 provides an illustration of the biennial production possibility frontier and measure of output-oriented technical efficiency with reference to it for a firm, producing a single output from a single input, observed in two time periods *t* and *t+1* (point A and B respectively). The VRS frontiers for period *t* and *t* +1 are indicated by $K_0L_0M_0$- extension and $K_1 L_1M_1$ - extension respectively. The rays through origin OP_0 and OP_1 represent the CRS frontiers for period *t* and period *t* +1respectively. The biennial VRS frontier is indicated by the broken line $K_1 L_1 DFM_0$ -

extension and the biennial CRS frontier in this case coincides with that of period *t* +1. Output-oriented technical efficiency of the firm with reference to CRS biennial frontier in period *t* is

$TE_c^B(x^t, y^t) = \left(\frac{A_t X^t}{QX^t}\right)$ and that for period t+1 is $TE_c^B(x^{t+1}, y^{t+1}) = \left(\frac{A_{t+1} X^{t+1}}{RX^{t+1}}\right)$. Similarly with reference to the VRS biennial frontier, $TE_v^B(x^t, y^t) = \left(\frac{A_t X^t}{DX^t}\right)$ and $TE_v^B(x^{t+1}, y^{t+1}) = \left(\frac{A_{t+1} X^{t+1}}{FX^{t+1}}\right)$ show the levels of technical efficiency for the period t and t+1 respectively. The reference technology set T^B is defined as the convex hull of pooled data from both period *t* and *t* +1.

Using the output-oriented technical efficiency scores with reference to a CRS biennial frontier, the Biennial Malmquist Productivity Index of the firm *s* producing a single output from multiple inputs is measured as (Since the Biennial Malmquist Index of productivity uses the biennial CRS production possibility set, which includes the period *t* and *t+1* sets, one need not to calculate a "geometric mean" of two productivity indexes while measuring it)

$$M_c^B(x_s^t, y_s^t;\ x_s^{t+1}, y_s^{t+1}) = \frac{TE_c^B(x_s^{t+1}, y_s^{t+1})}{TE_c^B(x_s^t, y_s^t)} \quad \text{…5.6}$$

The decomposition of this Biennial Malmquist productivity index is

$$M_c^B(x_s^t, y_s^t;\ x_s^{t+1}, y_s^{t+1}) = TEC\ X\ TC\ X\ SEC \quad \text{…5.7}$$

Where

$$\text{TEC} = \frac{TE_v^{t+1}(x_s^{t+1}, y_s^{t+1})}{TE_v^t(x_s^t, y_s^t)}, \quad \text{…5.8}$$

$$\text{TC} = \frac{TE_v^B(x_s^{t+1}, y_s^{t+1}) / TE_v^{t+1}(x_s^{t+1}, y_s^{t+1})}{TE_v^B(x_s^t, y_s^t) / TE_v^t(x_s^t, y_s^t)}, \text{ and} \quad \text{…5.9}$$

$$\text{SEC} = \frac{TE_c^B(x_s^{t+1}, y_s^{t+1}) / TE_v^B(x_s^{t+1}, y_s^{t+1})}{TE_c^B(x_s^t, y_s^t) / TE_v^B(x_s^t, y_s^t)} \quad \text{…5.10}$$

Now from figure 2 one can define Biennial Malmquist productivity index as

$$M_c^B(x_s^t, y_s^t;\ x_s^{t+1}, y_s^{t+1}) = \frac{\left(\frac{A_{t+1}X^{t+1}}{RX^{t+1}}\right)}{\left(\frac{A_tX^t}{QX^t}\right)}$$

The decomposition of this Malmquist productivity index is

$M_c^B(x_s^t, y_s^t;\ x_s^{t+1}, y_s^{t+1})$

$$= \frac{(A_{t+1}X^{t+1}/EX^{t+1})}{(A_tX^t/CX^t)}\ X\ \frac{(A_{t+1}X^{t+1}/FX^{t+1})/(A_{t+1}X^{t+1}/EX^{t+1})}{(A_tX^t/DX^t)/(A_tX^t/CX^t)}\ X\ \frac{(A_{t+1}X^{t+1}/RX^{t+1})/(A_{t+1}X^{t+1}/FX^{t+1})}{(A_tX^t/QX^t)/(A_tX^t/DX^t)}$$

Where

TEC= $\frac{(A_{t+1}X^{t+1}/EX^{t+1})}{(A_tX^t/CX^t)}$

TC = $\frac{(A_{t+1}X^{t+1}/FX^{t+1})/(A_{t+1}X^{t+1}/EX^{t+1})}{(A_tX^t/DX^t)/(A_tX^t/CX^t)}$

SEC = $\frac{(A_{t+1}X^{t+1}/RX^{t+1})/(A_{t+1}X^{t+1}/FX^{t+1})}{(A_tX^t/QX^t)/(A_tX^t/DX^t)}$

The appropriate DEA model to estimate period *t* output-oriented technical efficiency $TE_c^B(x_s^t, y_s^t)$ of firm *s*, with reference to a CRS biennial production possibility set is

$$\varphi_s^* = \max \varphi$$

Subject to $\sum_{k=t,t+1}\sum_{j=1}^{n_k}\lambda_j^k y_j^k \geq \varphi y_s^t;$

$$\sum_{k=t,t+1}\sum_{j=1}^{n_k}\lambda_j^k x_j^k \leq x_s^t;$$

$$\lambda_j^k \geq 0;$$

Where n_k is the number of observed firm in the period k and $TE_c^B(x_s^t, y_s^t) = \frac{1}{\varphi_s^*}$

Period t output oriented technical efficiency $TE_v^B(x_s^t, y_s^t)$ of firm s, with reference to a VRS biennial production possibility set is

$$\varphi_s^* = \max \varphi$$

Subject to $\sum_{k=t,t+1} \sum_{j=1}^{n_k} \lambda_j^k y_j^k \geq \varphi y_s^t$;

$$\sum_{k=t,t+1} \sum_{j=1}^{n_k} \lambda_j^k x_j^k \leq x_s^t;$$

$$\sum_{k=t,t+1} \sum_{j=1}^{n_k} \lambda_j^k = 1;$$

$$\lambda_j^k \geq 0;$$

Where n_k is the number of observed firm in the period k and $TE_c^B(x_s^t, y_s^t) = \frac{1}{\varphi_s^*}$

5.2.2 Determinants of TFPG: The use of Simultaneous Panel Regression

TFPG is basically dependent on the growth of technology along with the other factors. In the context of agriculture one possible way is that the growth of technology can be represented by the growth of HYV uses. On the other hand, the growth of HYV uses in turn may be dependent on the TFPG itself in association with the other factors. Thus one can think of a simultaneous kind of relationship between TFPG and growth of HYV uses. The present chapter uses a simultaneous panel regression model for estimating the determinants of TFPG followings the same methodology as described in Chapter-3.

Equation Specifying Total factor Productivity Growth:

In order to explain the variation in TFPG following explanatory variables are considered:

- **Growth of HYV Uses (HYV):** It will be interesting to see whether the use of HYV has any role to play in promoting TFPG of major crops. The variable HYV is measured by the percentage of the cultivated area using high yielding varieties of seeds.
- **Growth of Government irrigation (GI) or Private irrigation (PI):** Another important determinant of TFPG is the irrigation. In order to test the role of Government irrigation vis-s-vis

Private irrigation in promoting TFPG the variable GI representing share of Government irrigation in total irrigation and the variable private irrigation measuring share of Private irrigation in total irrigation is taken into account because in the post-Green Revolution era, the newly introduced high yielding variety seeds and chemical fertilizers have greatly enhanced the importance of assured supply of water through deep well and canal irrigation

- **Growth of Rainfall (RF):** A significant important factor in this reverence is the amount of rainfall. It is well known that the production of Indian agriculture is heavily dependent upon the monsoon rain of the country. So to find out whether rainfall is a significant factor in promoting total factor productivity growth, the variable RF i.e. the amount of annual rainfall in the state in a given year, is taken in to account as one of the possible explanatory variables.

- **Growth of Government expenditure on agricultural education, research, and extension (E):** Government expenditure on agricultural education, research, and extension has a positive role on t production because they provides more information about the input uncertainty to the farmers. So if the expenditure on agricultural education, research, and extension has increased then farmers became more aware about the production uncertainty and they can take more preventive measures in the farming and get higher growth and hence can promote TFPG. Government expenditure on agricultural education, research and extension **(E)** is the amount of expenditure divided by total area under agricultural operation.

- **Growth of Rural literacy (RL)**: Rural literacy also has may have a positive impact on the TFPG of different crops because more literacy among rural people implies that people are more able to use the modern technology more efficiently. So, TFPG may be affected by the literacy rate of the rural sector.

- **Growth of Agricultural Loan (AL):** Another important determinant is the agricultural loan because agricultural loan for the farmers is necessary for purchasing more HYV seeds, Chemical Fertilizer, Tractors, Pumps, Electricity etc. When a farmer uses these kinds of modern technologies the TFPG must increase significantly. Agricultural loan **(AL)** is measured by the total amount of credit issued by rural banks and agricultural cooperatives per acre of cultivated area in the state.

- **Growth of Inequality in Distribution of Operational Land Holding (G):** In agriculture, land reforms and lowering of concentration of ownership occupies an important position for output growth. From the data of marginal holdings of land and number of farmers one can construct the Gini co-efficient for the distribution of operational land holding. Several country level studies looked at the likely relationship between land distribution and productivity. For example Besley and Burgess (2000) argued that in India, land reforms had their maximum effect in states with greatest initial land inequality. Jeon and Kim (2000) found significant productivity gains from land reforms in Korea during 1950s. Banerjee and Iyer (2005) while investigating the historical nature of land distribution in India locate that states initially having higher land inequality had lower productivity even after land reform took place. A study by Vollarth (2007) using cross country data on inequality in operational holding of agricultural land reform form Deininger and Squire (1998) pointed out the land distribution issue and also the matter of international agricultural productivity. While estimating agricultural production function he found the Gini coefficient for land holdings to have a negative significant relationship with productivity. Now all the above mentioned studies have found significant relationship between distribution of land holding and either efficiency or productivity. So, it will be interesting to see how the distribution of operational land holding affects the total factor productivity growth. The inequality of distribution of operational land holding is measured by the Gini ratio **(G)** and was constructed from the data on Census of agriculture.

Using these above explanatory variables and some preliminary estimate one can have the following specification of TFPG, which is specified as *Pro*. From these preliminary estimates it follows that the specification of productivity growth equation in fact varies from crop to crop.

In case of Rice:

$$Pro = f(RF, RF * RF, HYV, HYV * PI, PI, AL, RL, E, G, G * G, AL * PI) \quad \ldots 1A$$

In case of Wheat:

$$Pro = f(RF, RF * RF, HYV, HYV * HYV, GI, AL, RL, E, G, G * G) \quad \ldots 1B$$

In case of Jowar:

$$Pro = f(RF, RF * RF, HYV, HYV * HYV, GI, AL, E, G, G * G) \quad \ldots 1C$$

Equation Specifying Growth of HYV Uses:

The variation of HYV Uses is explained by considering the following variables:

- **Growth of Output (GR):** It is well known that introduction of Green Revolution policy in 1966 specifically the use of HYV seeds had increased the growth of output in case of rice and wheat in the northern states in India. With this sudden hike in the growth of output farmers were used more and more HYV seeds to get more and more output. So, it will be interesting to see whether the TFPG has any role to play in promoting HYV uses in case of rice production.
- **Growth of Government irrigation (GI) or Private irrigation (PI):** Another important determinant of HYV uses is Government irrigation vis-a-vis Private irrigation because in the post-Green Revolution era, in order to use HYV seeds efficiently the importance of assured supply of water through deep well and canal irrigation is needed. So, it will be interesting to see the effect of Government irrigation vis-à-vis Private irrigation on the HYV uses.
- **Growth of Government expenditure on agricultural education, research, and extension (E):** Government expenditure on agricultural education, research, and extension has a positive role on the HYV uses because as Government expenditure on agricultural education, research, and extension increases the possibility of the invention and use of new variety of HYV seeds becomes higher.
- **Growth of Rural literacy (RL)**: Similarly Rural literacy also has a positive impact on the HYV uses because as rural literacy goes up, then farmers become more and more educated and hence may be more acquainted with the HYV seed and their uses, which in turn will put a positive effect of growth of HYV uses.
- **Growth of Agricultural Loan (AL):** Another important determinant is the agricultural loan because agricultural loan for the farmers is necessary for purchasing more HYV seeds, Chemical Fertilizer, Tractors, Pumps, Electricity etc. So, there exists a positive relationship between agricultural loan and HYV uses.
- Apart from these determinants this study has also included regional dummy to incorporate the regional variation in the total factor productivity growth. The benchmark region is the one for which the impact of the green revolution is maximum. For each crop it was found to be the northern region.

For rice, apart from Northern region, the other contributing regions are Southern, Middle and Eastern. Hence for rice

$D_i = 1$ if states belong to the ith region. (i= Southern and Eastern region)

= 0 otherwise.

Similarly in case of wheat apart from northern region the other two regions are Western and Eastern region.

So, $D_i = 1$ if states belong to the ith region. (i= Western and Eastern region)

= 0 otherwise.

In case of Jowar also southern region or Western Region are considered apart from northern region.

So, $D_i = 1$ if states belong to the southern region or Western Region.

= 0 otherwise.

Using these above explanatory variables and some preliminary estimate one can have the following specification of growth of HYV Uses which is specified as HYV. From these preliminary estimates it follows that the specification of Growth of HYV uses in fact varies from crop to crop which are as below:

In case of Rice:

$$HYV = f(Pro, Pro * Pro, PI, AL, E, RL \text{ and Regional Dummies}) \quad \ldots 2A$$

In case of Wheat:

$$HYV = f(Pro, Pro * Pro, GI, AL, E, RL \text{ and Regional Dummies}) \quad \ldots 2B$$

In case of Jowar:

$$HYV = f(Pro, Pro * Pro, GI, AL, E, RL, Regional\ Dummies) \quad \ldots 2C$$

Now these two sets of equations satisfy both order and rank condition for simultaneous equation system. In fact the model is over identified. We have solved the identification problem by imposing exclusion restriction. It is found that each of the two equation contain separate variables and hence the mongrel equation is easily differentiable from the growth equation and growth of HYV equation and hence both the equations are identified.

Method for Estimation:

Problem of Simultaneity

To address the problem, a two stage method of estimation is adopted.

Two stage estimation method:

Stage 1: Replacing the HYV uses from equation (2A) into equation (1A) or (2B) into equation (1B) or (2C) into equation (1C) one can express TFPG as a function of other variables except HYV uses. This is the reduced form equation of total factor productivity growth. Similarly, replacing TFPG from equation (1A) into equation (2A) or (1B) into equation (2B) or (1C) into equation (2C) one can get HYV uses is function of other variables except growth of output. This is the reduced form equation of HYV uses.

Now, from the reduced form equations of TFPG and growth of HYV uses one can get reduced form parameters and hence can obtain estimated values of TFPG and Growth of HYV uses.

Stage 2: One can replace this estimated value of TFPG as obtained from stage 1 in equation (2A, 2B or 2C for Rice, Wheat and Jowar respectively) to get the final estimate of the HYV uses using the panel model under SUR framework. Similarly, one can replace the estimated value of HYV uses as obtained from stage 1 in equation (1A, 1B and 1C for Rice, Wheat and Jowar respectively) to get the final estimate of TFPG.

Now for detailed methodology of Seemingly unrelated regression model (SUR) framework, Cross Section SUR or Contemporaneous Covariances, White Cross-Section or Cross Section Heteroscedasticity see Chapter-3.

5.2.3 The Data sources

In this chapter we have considered the input and output data for estimating the productivity growth. The input and outputs are as follows:

Output: Production of each Crop

Inputs:

I. Seed (Kg.)
II. Fertilizer (Kg. Nutrients)
III. Manure (Qtl.)
IV. AREA ('000 Hectares)
V. Human Labour (Man Hrs.)[4]

All the data has been collected from the different issues of the Statistical abstract, Agriculture at a Glance, Agriculture in Brief, Handbook of Statistics on Indian Economy, *www.indianstat.com* (an online commercial data service), Cost of Cultivation data published by the Government of India.

The productivity analysis for each of the crop as considered in Chapter-3 and 4 cannot be done due to the unavailability of state-wise cost of cultivation data from 1970-71 to 2013-14. In this chapter we are considering only three crops i.e. Rice, Wheat and Jowar for which the consistent data are available. The major producing states of these crops are as follows:

✓ Rice- Andhra Pradesh, Assam, Bihar, Haryana, Karnataka, Madhya Pradesh, Orissa, Punjab, Tamil Nadu, Uttar Pradesh, West Bengal

✓ Wheat- Bihar, Haryana, Madhya Pradesh, Rajasthan, Punjab, Uttar Pradesh

[4] Animal labour is not included as the determinant because most of the entries under animal labour are zero or unavailable.

- ✓ Jowar(Sorghum)- Andhra Pradesh, Karnataka, Maharashtra, Rajasthan and Tamil Nadu.

5.3 Results of estimation

All the results are presented in Tables 5.1 to 5.36.

5.3.1 Results of Average Annual Rate of Changes of TFPG

The TFPG for each of the years, each of the crops and each of the states are estimated. The results are then summarized to generate the information regarding the average annual rate of changes of TFPG for each crop. Such estimation results for Rice, Wheat and Jowar are presented in Tables-5.1, 5.2 and 5.3 respectively.

From Table 5.1 in case of **Rice** it can be concluded that overall average annual rate of change of TFPG in case of rice is 1.94% for the period 1970-71 to 2013-14. Now if one consider the state wise results the average annual rate of change of TFPG is negative only in case of AS (-0.48%) for the period 1970-71 to 2013-14. This rate of changes of TFPG is highest in case of HA (3.67%) followed by PU (2.83%), OR (2.42%), BI (2.33%), KA (2.04%), MP (1.94%), WB (1.08%), UP (1.21%), TN (1.009%) and AP (0.75%). The decadal average annual rate of change of TFPG are also estimated. For decadal analysis the overall period 1970-71 to 2013-14 is broken down into four sub periods 1970-79, 1980-89, 1990-99 and 2000-2013. The result of decadal average annual rate of change of TFPG implies that this change is highest for the period 1970-79 (4.35%). This change may be due to the successful implementation of green revolution policies in that decade. The overall average annual rate of change of TFPG declined from 4.35% in 1970-79 to 2.87% in 1980-89 to 1.88% in 1990-99. In the period 2000-2013 the average annual rate of change of TFPG is negative (-1.96%). This may occur because nine among the eleven major rice producing states experienced a negative average annual rate of changes of TFPG for the period 2000-2013. The overall decline in average annual rate of changes of TFPG may be visualized from its decline for 10 states out of 11 for the period 1970-79 to 1980-89 and 7 states out of 11 for the period 1980-89 to 1990-99 along with corresponding decline associated with the period 2000-2013.

From Table 5.2 it can be concluded that in case of **wheat** the average annual rate of change of TFPG is 1.19% for the entire sample period. But as in case of rice this annual growth rate decline from 1970-79 (4.43%) to 1980-89 (1.7%) to 1990-99 (1.15%). This annual growth rate is negative (-2.52%) for the period 2000-2013. average annual rate of change of TFPG is highest in case of 1970-79, may be due to the implementation of the green revolution policies in the Indian agriculture. During these period this annual rate is highest in case of PU (6.96%) followed by BI (6.31%), HA (5.3%), MP (4.54%), RA (2.43%) and UP (1.05%). During the period 1980-89 the annual growth rate is highest in case of MP (5.12%) followed by RA (4.2%), HA (2.55%), PU (1.69 %) and UP (1.5%). In case of BI this growth rate is negative (-4.88%). During the period 1990-99 the average annual rate of change of TFPG is negative only in case of MP (-2.5%). This rate is highest in case of RA (4.26%). During the period 2000-2013 this annual growth rate is negative in case of five among the six major wheat producing states, only in case of BI this rate is positive (4.35%).

From Table 5.3 it can be concluded that as in case of rice and wheat the average annual rate of change of TFPG declined from 1970-79 (4.32%) to 1980-89 (4.15%) to 1990-99 (2.08%) in case of **Jowar**. This average annual rate of change of TFPG is negative (-2.22%) for the period 2000-2013. During the period 1970 to 1979 the average annual rate of change of TFPG is highest in case of TN (7.03%) followed by MA (6.25%), AP (4.62%), RA (3.56%) and KA (0.12%). During the period 1980-89 this rate of growth is again highest in case of TN (7.77%) and lowest in case of RA (2.01%). But during 1990-99 TN experienced a negative growth rate (-2.08%). During this period the rate of growth is highest in case of AP (3.8%). During 2000-2013 the annual average rate of TFPG is negative in case of AP (-5.24%), MA (2.93%) and TN (-5.38%).

5.3.2 Results of Decomposition of TFPG

The estimated results of TFPG are then decomposed into Efficiency Changes, Scale Efficiency Changes and Technical Changes following the formula 5.7 to 5.10. For each of the crop, the overall changes in the decomposition of TFPG as well as its decadal changes over the period 1970-79, 1980-89, 1990-99 and 2000-2013 are estimated.

For **Rice** overall and the decadal changes are presented in Table 5.4 to 5.8. Entries in column TEC show average annual changes in the level of technical efficiency over time for each state, a value greater than unity for this component implies that a state experienced improvement in technical efficiency over the period. Similarly, an entry with value greater (less) than unity in column TC reflects technological progress (regress) in a state over time. The change in scale efficiency over time for each state is reported in column SEC, with a value exceeding one again signaling an improvement in scale efficiency. From the results of Table 5.4 it can be concluded that productivity growth is mostly driven by the change in the scale efficiency for the entire sample period. The change in the technical efficiency is another major factor behind the increase in the productivity growth. The change in the technology has the lowest impact on the increase in the productivity. So it can be concluded that better utilization of factors of production and changes in the scale may pushed the sates to be on higher TFPG in case of rice for the period 1970 to 2013. Now for this period AP, OR and WB experienced a technological regress and WB experienced a decline in the scale efficiency.

For **Wheat** overall and the decadal changes are presented in Tables 5.9 to 5.13. Arguing in a similar fashion as before from the results of the Table 5.9 it can be concluded that in case of rice the productivity growth is mostly driven by the change in the scale efficiency for the entire sample period. The change in the technology has also an impact on the increase in the productivity. Because three states namely HA, PU and RA showed technological progress for the entire sample period. So it can be concluded that use of superior technology and changes in the scale may pushed the sates to be on higher TFPG in case of wheat for the period 1970 to 2013. In case of HA and PU the technological progress occurred only for the period 1970-79. But for the rest of the period HA and PU experienced either no technological progress or technological regress. In case of BI and RA apart from scale efficiency change productivity has also changed due to improvement in the technological efficiency. So, for these states better utilization of factors of production may also push up the states to be on higher TFPG.

For **Jowar** overall and the decadal changes are presented in Table 5.14 to 5.18. Arguing in a similar fashion as before from the Table 5.14 it can concluded that in case of rice and wheat productivity growth for jowar is also mostly driven by the change in the scale efficiency for the entire sample period. In case of AP and KA apart from scale efficiency change productivity has also changed due to improvement in the technological efficiency and change in the technology. For AP and KA there is an improvement in the technical efficiency during the entire sample period. Not only this, these two states showed technological progress during this period. Thus for these two states better utilization of factors of production, superior technology and changes in the scale may push up the states to be on higher TFPG for jowar over the period 1970 to 2013.

Thus in conclusion it can be said that scale changes are the most important factor causing the productivity changes for all three crops. Among the two other alternative sources of TFPG, efficiency changes dominates over technical changes in case of rice and the reverse is true for wheat. For jowar no such conclusive statement can be made regarding the dominance of the technical changes over the efficiency changes or vice-versa. In case of rice, the improvement in the technical efficiency may push the states to a higher TFPG. In case of wheat the superior technology is another factor behind the improvement in TFPG.

There also exists a strong interstate variation behind the causes of improvement in TFPG. During the same sub period some states experienced technological progress where as some other have technological regress. Also the decadal performance of a particular state varies regarding the relative movement of technological changes and efficiency changes. States experiencing technological progress in some decade has shown technological regress in the other decade. Same conclusion holds for technical efficiency also. Regarding scale efficiency change it can be inferred that most of the states have experienced an improvement in the scale for most of the decade.

5.3.3 Results of Determinants of TFPG

The present chapter explains the factors influencing TFPG for each of the crop; Rice, Wheat and Jowar by using simultaneous panel approach.

For **Rice,** the complete results for the determinant analysis using simultaneous panel approach are presented in Tables-5.19 to 5.24, of which Table 5.19 and 5.20 represents estimated productivity growth equation and growth of HYV uses equation respectively. Both the estimated equations in the models are found to be nonlinear. Thus, in order to find out the effect of explanatory variable one needs to calculate the marginal effect and to test for non linearity. The marginal effect of productivity growth equation and growth of HYV equation are presented in Table 5.21 and 5.23 respectively. The results of Wald test for testing whether the coefficients corresponding to the non linear variable are in-fact zero, are presented in Table 5.22 and 5.24 for productivity growth equation and growth of HYV equation respectively.

The estimated models also reports Adjusted R^2 which represents the overall fit of the model, which is based on the difference between residual sum of squares from the estimated model and the sum of square from a single constant only specification, not from a fixed effect only specification. High value of Adjusted R^2 shows that the fitted models are reasonably good.

Explanation of Productivity Growth Equation for Rice:

From Table 5.19 it can be concluded that the productivity of rice is non-linearly and significantly related with growth of rainfall, HYV uses, private irrigation, and Agricultural loan. The marginal effects of these variables are positive implying that all these explanatory variables have a positive influence on the productivity of rice. The coefficient of first polynomial of rainfall is positive suggesting an increase in rainfall will increase the TFPG but since the coefficient of second polynomial of rainfall is negative it in turn implies that too much rainfall may affect the productivity of rice in the reverse way.

Coming to the other determinants of TFPG i.e., growth of HYV uses, the sole effect of HYV uses is positive and statistically significant suggesting an increase in growth of HYV uses will in turn induce TFPG. The interaction term between Growth of HYV uses and Growth of Private irrigation is negative and statistically significant. But the marginal effect of growth of HYV uses is positive which in turn implies that positive sole effect dominates the negative interaction effect in case of HYV uses.

Private irrigation and agricultural loan are also contributing to the TFPG of rice. The sole effect of Private irrigation and Agricultural loan on productivity is positive and statistically significant. There exists some interaction effect between Private irrigation and Agricultural loan and the sign of such interaction term is positive. Thus on the whole the effect of Private irrigation and Agricultural loan on productivity is positive.

The results of Wald statistics in the Table 5.22 showed the importance of inclusion of nonlinear relationship of rainfall, HYV uses, agricultural loan and private irrigation as explanatory variable in TFPG equation.

The TFPG equation of rice is also positively and linearly influenced by Government expenditure on Agricultural research and extension and rural literacy implying that an increase in Government expenditure on Agricultural research and extension or rural literacy will induce TFPG of Rice.

Further, there exists a negative relation between inequality in the distribution of operational land holding and the productivity of rice, suggesting that an increase in inequality in distribution of operational land holding may adversely affect the TFPG.

Explanation of Growth of HYV uses Equation for Rice:

From the results of Table 5.20 it can be found that HYV uses is positive and significantly related with TFPG, private irrigation, Government expenditure on Agricultural research and extension, rural literacy and agricultural loan.

There exists a non-linear relationship between Growth of HYV uses and TFPG. The coefficient of first polynomial of TFPG is positive implying that an increase in TFPG will increase the Growth of HYV uses. But as the coefficients of second polynomial is negative which implies that although at the primary stage an increase in TFPG will be associated with an increase in growth of HYV uses, but it happens upto a level of TFPG, and after that an increase in TFPG will led to a downward movement of HYV uses. The marginal effect of TFPG on HYV uses is positive implying that on the whole the effect of TFPG on HYV uses are positive.

Apart from this growth of HYV uses is positively and significantly related with private irrigation, Government expenditure on Agricultural research and extension, rural literacy and agricultural loan but these relations are linear in nature implying that an increase in private irrigation, Government expenditure on Agricultural research and extension, rural literacy and agricultural loan will promote the growth of HYV uses. The result of Wald statistic in Table 5.24 shows the importance of inclusion of TFPG as a non linear the explanatory variable.

Other than these explanatory variables HYV uses is also influenced by regional variability. The dummy for southern region and eastern region taking northern as benchmark is negative and statistically significant implying that in these two regions growth of HYV seeds is less as compared to the northern region.

For **Wheat** the complete results of the determinant analysis using simultaneous panel approach are presented in Table-5.25 to 5.30, of which Table 5.25 and 5.26 represent estimated TFPG equation and growth of HYV uses equation respectively. As in case of rice it is found that both the estimated equations for wheat are nonlinear. Thus, in order to find out the effect of explanatory variable showing non-linear relationship one needs to calculate the marginal effect. The marginal effect of productivity growth equation and growth of HYV equation are presented in Table 5.27 and 5.29 respectively. The results of Wald test used for testing whether the coefficients corresponding to the non linear variable are in-fact zero, are presented in Table 5.28 and 5.30 for TFPG equation and growth of HYV equation respectively.

The Adjusted R^2 shows that the fitted models are reasonably good.

Explanation of Productivity Growth Equation for Wheat:

From Table 5.25 it can be concluded that the productivity of wheat is positively and significantly related with growth of rainfall and HYV uses. These relations are non-linear in nature. For both these variables the coefficients of first polynomial are positive and the coefficients of second polynomial are negative implying that there exists an inverted U shaped relationship with both these variables and TFPG for wheat. This result suggests that too much rainfall or growth of HYV uses may affect the TFPG of wheat in reverse way. The marginal effect of these variables are positive implying that overall effects of these explanatory variables on TFPG of wheat are positive.

On the other hand, government irrigation, agricultural loan, rural literacy and Government expenditure on Agricultural research and extension has a positive and significant effect on the productivity of wheat but this relationship is linear in nature implying that an increase in government irrigation, agricultural loan, rural literacy and Government expenditure on Agricultural research and extension will stimulate the TFPG of wheat.

Apart from these variables there also exists a negative relation between inequality in the distribution of operational land holding and the productivity of wheat. This relation is non-linear in nature. The first polynomial of inequality in the distribution of operational land holding is negative and second polynomial of inequality in the distribution of operational land holding is positive implying increase in inequality in distribution of operational land holding may adversely affect the productivity. The marginal effect of this variable is positive implying that an overall effect of this explanatory variable on TFPG of wheat is positive.

The results of Wald statistics in the Table 5.28 showed the importance of the inclusion of nonlinearity of rainfall, HYV uses and inequality in distribution of operational land holding as explanatory variables.

Explanation of Growth of HYV uses Equation for Wheat:

Considering the factors explaining the variation of HYV uses it can be found from the results of Table 5.26 that growth of HYV uses is positive and significantly related with government irrigation, agricultural loan, Government expenditure on Agricultural research and extension and rural literacy. These relationships are linear in nature implying that an increase in the government irrigation, agricultural loan, Government expenditure on Agricultural research and extension and rural literacy will induce the growth of HYV uses.

On the other hand, the growth of HYV uses is non-linearly related with productivity of wheat. The explanation of the non linearity is same as in case of rice. The marginal effect of this variable is positive implying that an overall effect of this explanatory variable on growth of HYV uses of wheat is positive. The result of Wald statistic in Table 5.30 shows the importance of the inclusion of nonlinearity of TFPG of wheat.

Apart from these explanatory variables HYV uses is also influenced by regional variability. The dummy for western region and eastern region taking northern as benchmark is negative and statistically significant implying that in these two regions growth of HYV seeds is less as compared to the northern region.

For **Jowar** the complete results of the determinant analysis using simultaneous panel approach are presented in Table-5.31 to 5.36, of which Table 5.31 and 5.32 represents estimated productivity growth equation and growth of HYV uses equation respectively. As both the estimated equations in the models are nonlinear, in order to find out the effect of explanatory variable showing non-linear relationship one needs to calculate the marginal effect. The marginal effect of productivity growth equation and growth of HYV equation are presented in Table 5.33

and 5.35 respectively. The results of Wald test are presented in Table 5.34 and 5.36 for productivity growth equation and growth of HYV equation respectively.

The Adjusted R^2 shows that the fitted models are reasonably good.

Explanation of Productivity Growth Equation for Jowar:

From Table 5.31 it can be concluded that the productivity of jowar is positively and significantly related with rainfall and HYV uses. These relations are non-linear in nature. The coefficients of first polynomial of rainfall and HYV are positive and the coefficients of second polynomial of rainfall and HYV are negative. The implication of this result is same as described in case of wheat. The marginal effects of these variables are positive implying that all these explanatory variables have a positive influence on the productivity of jowar. The result of Wald statistic in Table 5.34 shows the importance of the inclusion of nonlinearity of these variables.

On the other hand, government irrigation, Government expenditure on Agricultural research and extension and agricultural loan has a positive and significant effect on the productivity of jowar but this relationship is linear in nature implying that an increase in government irrigation, Government expenditure on Agricultural research and extension and agricultural loan will encourage the TFPG of Jowar.

There also exists a negative relation between inequality in the distribution of operational land holding and the productivity of jowar. This relation is non-linear in nature. The first polynomial of inequality in the distribution of operational land holding is negative and second polynomial of inequality in the distribution of operational land holding is positive. But the marginal effect of inequality in the distribution of operational land holding is negative implying increase in inequality in distribution of operational land holding may adversely affect the productivity. The result of Wald statistic in Table 5.34 shows the importance of the inclusion of nonlinearity of this variable.

Explanation of Growth of HYV uses Equation for Jowar:

Considering the factors explaining the variation in growth of HYV uses it can be found from the results of Table 5.32 that growth of HYV uses is positive and significantly related with government irrigation, agricultural loan, Government expenditure on Agricultural research and extension and rural literacy. These relations are linear in nature implying an increase in government irrigation, agricultural loan, Government expenditure on Agricultural research and extension and rural literacy will induce the growth of HYV uses.

There exists a non-linear relationship between TFPG of jowar and HYV uses. The explanation of this relationship is the same as in the case of rice and wheat. The marginal effect of TFPG is positive implying that overall effect of TFPG on growth of HYV of jowar is positive. The result of Wald statistic in Table 5.36 shows the importance of the inclusion of this variable.

Apart from these explanatory variables HYV uses is also influenced by regional variability. The dummy for southern region and western region taking northern as benchmark is negative and statistically significant implying that in these two regions growth of HYV seeds is less as compared to the northern region.

5.4 Conclusion

The present chapter estimates TFPG of Indian agriculture for three selected crops Rice, Wheat and Jowar over the period 1970-71 to 2013-14 considering the major producing states of these crops. Biennial Malmquist Index (BMI) of non-parametric method of Data Envelopment Analysis (DEA) is used for estimation. After estimating the TFPG the major factors influencing TFPG is explained. TFPG is basically dependent on the growth of technology along with the other factor. In the context of agriculture one possible way is that the growth of technology can be represented by the growth of HYV uses. On the other hand, the growth of HYV uses in turn may be dependent on the TFPG itself in association with the other factors. Thus one can think of a simultaneous kind of relationship between TFPG and growth of HYV uses. So, for determination of major explanatory variables this chapter considers the problem of simultaneity between TFPG and growth of HYV uses under a Seemingly Unrelated Regression (SUR) framework, adjusted for contemporaneous correlation across units and cross-section heteroscedasticity is taken care by White Cross-Section.

The results suggest that in case of rice average annual rate of change of TFPG is 1.94% for the period 1970-71 to 2013-14. Not only that, the result of decadal average annual rate of change of TFPG implies that this change is highest for the period 1970-79 (4.35%). Apart from these results there exists a strong state wise variation in terms of average annual rate of change of TFPG. The overall average annual rate of change of TFPG declined from 4.35% in 1970-79 to 2.87% in 1980-89 to 1.88% in 1990-99. In the period 2000-2013 the average annual rate of change of TFPG is negative (-1.96%). In case of wheat, average annual rate of change of TFPG declined from 1970-79 (4.43%) to 1980-89 (1.7%) to 1990-99 (1.15%). This average annual rate of change of TFPG is negative (-2.52%) for the period 2000-2013 as in case of rice. In case of jowar, the average annual rate of change of TFPG declined steadily from 1970-79 (4.32%) to 1980-89 (4.15%) to 1990-99 (2.08%). This average annual rate of change of TFPG is negative (-2.22%) for the period 2000-2013 as in the case of rice and wheat.

From the results of decomposition of Malmquist Index it can be concluded that scale changes are the most important factor causing productivity changes for all the three crops. Among the two other alternative sources of TFPG, efficiency changes dominates over technical changes in case of rice and the reverse is true for wheat. For jowar no such conclusive statement can be made regarding the dominance of the technical changes over the efficiency changes or vice-versa. In case of rice the improvement in the technical efficiency may push the states to a higher growth path. In case of wheat the superior technology is another factor for the improvement in the TFPG.

Apart from this there exists a strong interstate variation behind the causes of the improvement in the TFPG. Some states experienced technological progress where as some other have technological regress during the same sub period. Also the decadal performance of a particular state varies regarding the relative movement of technological changes and efficiency changes. States experiencing technological progress in some decade faces technological regress in the other decade. Same thing happened in case of change in the technical efficiency also. In case of change in the scale most of the states experienced an improvement in the scale for most of the decade.

Now from the results of the major determinants it can be concluded that the TFPG of rice is non-linearly and significantly related with rainfall, HYV uses, private irrigation and Agricultural loan. Although there exists a non-linear relationship between these variables with the TFPG of rice but the marginal effect of these variables is positive implying that an increase in these variables will induce TFPG of rice. On the other hand, rural literacy and Government expenditure on Agricultural research and extension has a positive and significant effect on the TFPG of rice but these relationships are linear in nature. There exists a non-linear relation between inequality in the distribution of operational land holding and the TFPG of rice but the marginal effect of inequality in the distribution of operational land holding is negative implying that an increase in inequality in distribution of operational land holding may adversely affect the TFPG. In case of growth of HYV use equation there exists a non-linear relationship between growth of HYV uses and TFPG but the marginal effect of TFPG is positive implying that an increase in TFPG will stimulate growth of HYV uses. Apart from this growth of HYV uses is positively, linearly and significantly related with private irrigation, Government expenditure on Agricultural research and extension, rural literacy and agricultural loan but these relations are linear in nature.

In case of wheat the TFPG of wheat is positively and significantly related with growth of rainfall and HYV uses. These relations are non-linear in nature but positive marginal effect of these variables implies that an increase in these variables will induce TFPG of wheat. On the other hand, government irrigation, agricultural loan, rural literacy and Government expenditure on Agricultural research and extension has a positive and significant effect on the productivity of wheat but this relationship is not non-linear in nature. There exists a non-linear relation between inequality in the distribution of operational land holding and the productivity of wheat but a negative marginal effect of inequality in the distribution of operational land holding implies that an increase in the inequality of distribution of land holding will decrease TFPG of wheat. Considering the factors explaining the variation in HYV uses it can be found that HYV uses is positive, linearly and significantly related with government irrigation, agricultural loan, Government expenditure on Agricultural research and extension and rural literacy. Growth of HYV uses of wheat is nonlinearly and significantly related with TFPG of wheat. Although there exists an inverted U shape relation between these two variables but positive marginal effect of TFPG of wheat implies that an increase in TFPG of wheat will induce the growth of HYV uses of wheat.

In case of jowar the productivity of jowar is positively and significantly related with rainfall and HYV uses. These relations are non-linear in nature as in case of rice and wheat. On the other hand, government irrigation, Government expenditure on Agricultural research and extension and agricultural loan has a positive and significant effect on the productivity of jowar but this relationship is linear in nature. There also exists a non-linear relation between inequality in the distribution of operational land holding and the productivity of jowar and the implication is as similar in case of rice and wheat. In case of growth of HYV uses equation it can be found that HYV uses is positive and significantly related with government irrigation, agricultural loan, Government expenditure on Agricultural research and extension and rural literacy. These relations are linear in nature. Similarly as in case of rice and wheat there exists a non-linear relationship between productivity of jowar and HYV uses.

Thus this result reveals that although the green revolution policies may push the TFPG in a higher level but the effect of green revolution policy may fade out over time. The analysis also reveals that in order to encourage total factor productivity growth, any policy changes that will lead to increase in the government and private irrigation, availability of agricultural loan, rural literacy, government expenditure on agricultural research and extension should be emphasized. In fact for each of the crop one can identify certain common policy that will boost up TFPG and the growth of HYV uses. These policies are of crucial importance because those have two way effects. By increasing the growth of HYV uses they will in turn also boost up TFPG. For example, the common policy variable that will boost up TFPG and growth of HYV uses are (i) private irrigation, availability of agricultural loan, rural literacy, government expenditure on agricultural research and extension for rice, (ii) Government irrigation, availability of agricultural loan, rural literacy, government expenditure on agricultural research and extension for wheat and (iii) Government irrigation, availability of agricultural loan, rural literacy, government expenditure on agricultural research and extension for jowar. Thus comparison of these common policy factors across different crops should be emphasized. Also heavy rainfall may hamper the total factor productivity growth. Although there exists non linear relationship (i) between TFPG and the growth of HYV uses, the marginal effect of HYV uses is positive implying that an increase in growth of HYV uses will push up TFPG and (ii) between TFPG and the inequality in operational land holding but the marginal effect of the inequality in the operational land holding is negative suggesting that an increase in inequality in operational land holding will reduce TFPG.

Table 5.1 Average Annual Rates of Total Factor Productivity Changes in Rice

	ALL YEAR	1970-79	1980-89	1990-99	2000-2013
AP	0.75	2.41	1.30	2.16	-2.87
AS	-0.484	4.342	-0.0000000051	-0.097	-6.183
BI	2.33	2.05	3.59	4.50	-0.83
HA	3.672	7.757	3.646	8.075	-4.788
KA	2.042	6.728	5.486	-1.463	-2.582
MP	1.942	1.882	1.464	1.407	3.014
OR	2.420	3.696	1.107	1.971	2.907
PU	2.835	6.557	4.650	3.083	-2.951
TN	1.009	5.617	0.912	-0.490	-2.003
UP	1.021	5.243	0.855	0.227	-2.243
WB	1.089	1.521	4.611	1.274	-3.052
OVER ALL	1.94	4.35	2.87	1.88	-1.96

Table 5.2 Average Annual Rates of Total Factor Productivity Changes in Wheat

	ALL YEAR	1970-79	1980-89	1990-99	2000-2013
BI	2.02	6.31	-4.88	2.29	4.35
HA	1.46	5.30	2.55	0.11	-2.13
MP	0.80	4.54	5.12	-2.50	-3.94
PU	1.23	6.96	1.69	1.51	-5.24
RA	1.42	2.43	4.20	4.26	-5.23
UP	0.22	1.05	1.50	1.24	-2.92
OVER ALL	1.19	4.43	1.70	1.15	-2.52

Table 5.3 Average Annual Rates of Total Factor Productivity Changes in Jowar

	ALL YEAR	1970-79	1980-89	1990-99	2000-2013
AP	1.65	4.62	3.40	3.80	-5.24
KA	2.50	0.12	5.37	2.77	1.74
MA	2.21	6.25	2.22	3.29	-2.93
RA	2.22	3.56	2.01	2.61	0.68
TN	1.84	7.03	7.77	-2.08	-5.38
OVER ALL	2.08	4.32	4.15	2.08	-2.22

Table 5.4: Results of productivity of Rice for the period 1970-71-2013-14

STATES	TEC	TC	SEC	MI
AP	1.002606	0.999826	1.004855	1.008384
AS	1	1	1.003671	1.003671
BI	1.008898	1.000224	1.004042	1.016672
HA	1.006225	1.000538	1.023092	1.023092
KA	1.011955	1.000035	1.011783	1.023915
MP	1.018135	1.007045	1.033359	1.03723
OR	1.039372	0.998469	1.012097	1.043963
PU	1.000000	1.001837	1.001620	1.003444
TN	1.006027	1.000103	1.003634	1.007248
UP	1.000575	1.000099	1.006344	1.007714
WB	1.000363	0.999081	0.999877	1.000332
AVERAGE	1.00856	1.000847	1.009507	1.014773

Table 5.5: Results of productivity of Rice for the period 1970-1979

STATES	TEC	TC	SEC	MI
AP	1.003637	0.997293	1.009389	1.00957
AS	1	1	1.012766	1.012766
BI	1	1	1.025298	1.025298
HA	1.027665	1.00239	1.045237	1.045237
KA	1.018794	1.007026	1.02335	1.029365
MP	1.016865	1.006604	1.100987	1.100987
OR	1.036375	1.004688	1.008074	1.067872
PU	1	1.007348	0.992953	1.000249
TN	1.000655	1.001978	0.989234	1.001976
UP	1.002555	1.000439	1.037633	1.043722
WB	1	1	1.004315	1.004315
AVERAGE	1.009686	1.001856	1.022658	1.030369

Table 5.6: Results of productivity of Rice for the period 1980-89

STATES	TEC	TC	SEC	MI
AP	1.001131	0.998845	1.004187	1.005059
AS	1	1	1	1
BI	0.981379	0.995239	1.007187	0.997855
HA	1	1	1.007262	1.007262
KA	0.976563	1.04393	0.986736	0.980389
MP	1.000844	1.019706	0.993329	0.993443
OR	1.034416	0.994718	0.989565	1.015511
PU	1	1	1.012385	1.012385
TN	1.009968	0.998413	1.014532	1.021792
UP	1	1	1.003419	1.003419
WB	1.0003	0.994853	0.996905	0.995389
AVERAGE	1.000418	1.004155	1.00141	1.002955

Table 5.7: Results of productivity of Rice for the period 1990-99

STATES	TEC	TC	SEC	MI
AP	1.001899	0.999577	1.004849	1.007618
AS	1	1	1.00013	1.00013
BI	1.054213	1.005655	1.017011	1.076861
HA	1	1	1.005474	1.005474
KA	1.037841	0.965324	1.030931	1.015116
MP	1.055671	1.002529	0.935253	0.948262
OR	0.986663	1.005488	1.047271	0.9888
PU	1	1	1.000248	1.000248
TN	1.000265	1.000129	1.002706	1.002828
UP	1	1	1.00068	1.00068
WB	1.001153	1.005943	0.995333	1.002856
AVERAGE	1.012519	0.998604	1.003626	1.004443

Table 5.8: Results of productivity of Rice for the period 2000-2013

STATES	TEC	TC	SEC	MI
AP	1.003745	1.003017	1.001757	1.011133
AS	1	1	1.001521	1.001521
BI	1	1	0.972003	0.972003
HA	1	1	1.03538	1.03538
KA	1.015001	1.000147	1.007683	1.025085
MP	1.000771	1	1.103605	1.105752
OR	1.094248	0.990408	1.003898	1.100415
PU	1	1	1.000892	1.000892
TN	1.012077	1.000083	1.006351	1.002356
UP	1	1	0.988553	0.988553
WB	1	0.995936	1.003077	0.999272
AVERAGE	1.01144	0.999054	1.011338	1.022033

Table 5.9: Results of productivity of Wheat for the period 1970-71-2013-14

STATES	TEC	TC	SEC	MI
BI	1.022924	1	1.030142	1.029578
HA	1	1.003973	1.003154	1.007184
MP	1	1	1.017103	1.017103
PU	1	1.006089	1.001392	1.007503
RA	1.0178	1.000506	1.012066	1.022772
UP	1	1	1.000697	1.000697
AVERAGE	1.006787	1.000084	1.010525	1.012216

Table 5.10: Results of productivity of Wheat for the period 1970-1979

STATES	TEC	TC	SEC	MI
BI	0.959147	1	1.002609	0.952715
HA	1	1.015890	1.014529	1.030650
MP	1	1	0.998382	0.998382
PU	1	1.024356	1.003587	1.028030
RA	1.079111	1.002249	0.989028	1.036611
UP	1	1	1.000529	1.000529
AVERAGE	1.006376	1.000375	1.000846	1.000461

Table 5.11: Results of productivity of Wheat for the period 1980-89

STATES	TEC	TC	SEC	MI
BI	1.088897	1	1.00836	1.015711
HA	1	1	1.001765	1.001765
MP	1	1	1.012926	1.012926
PU	1	1	1.000214	1.000214
RA	1	1	1.026946	1.026946
UP	1	1	1.001333	1.001333
AVERAGE	1.014816	1	1.008591	1.009816

Table 5.12: Results of productivity of Wheat for the period 1990-99

STATES	TEC	TC	SEC	MI
BI	1.039567	1	0.984059	0.967837
HA	1	1	1.000445	1.000445
MP	1	1	1.011995	1.011995
PU	1	1	1.003309	1.003309
RA	1	1	0.971915	0.971915
UP	1	1	1.00074	1.00074
AVERAGE	1.006594	1	0.99541	0.992707

Table 5.13: Results of productivity of Wheat for the period 2000-2013

STATES	TEC	TC	SEC	MI
BI	1	1	1.109657	1.109657
HA	1	1	0.995878	0.995878
MP	1	1	1.040862	1.040862
PU	1	1	0.998458	0.998458
RA	1	1	1.05389	1.05389
UP	1	1	1.000218	1.000218
AVERAGE	1	1	1.033161	1.033161

Table 5.14: Results of productivity of Jowar for the period 1970-71-2013-14

STATES	TEC	TC	SEC	MI
AP	1.017192	1.000387	1.038201	1.036858
KA	1.005429	1.0003	1.008754	1.01696
MA	1	1	1.032167	1.032167
RA	1	1	1.001524	1.001524
TN	1	1	1.009091	1.009091
AVERAGE	1.004524	1.000137	1.065948	1.06732

Table 5.15: Results of productivity of Jowar for the period 1970-1979

STATES	TEC	TC	SEC	MI
AP	1.07641	1.001722	1.100873	1.094901
KA	1	1	1.000636	1.000636
MA	1	1	1.074933	1.074933
RA	1	1	0.946513	0.946513
TN	1	1	1.018214	1.018214
AVERAGE	1.015282	1.000344	1.028234	1.027039

Table 5.16: Results of productivity of Jowar for the period 1980-89

STATES	TEC	TC	SEC	MI
AP	1	1.000815	1.059074	1.056245
KA	1	1	0.989103	0.989103
MA	1	1	0.991986	0.991986
RA	1	1	1.452436	1.452436
TN	1	1	0.995276	0.995276
AVERAGE	1	1.000163	1.097575	1.097009

Table 5.17: Results of productivity of Jowar for the period 1990-99

STATES	TEC	TC	SEC	MI
AP	1	1	1.018957	1.018957
KA	1.00319	1.000182	1.04394	1.042245
MA	1	1	1.065222	1.065222
RA	1	1	1.123716	1.123716
TN	1	1	1.033702	1.033702
AVERAGE	1.000638	1.000036	1.057107	1.056768

Table 5.18: Results of productivity of Jowar for the period 2000-2013

STATES	TEC	TC	SEC	MI
AP	1	1	1.019643	1.019643
KA	1.016843	1.000925	1.001273	1.032654
MA	1	1	1.003657	1.003657
RA	1	1	1.398258	1.398258
TN	1	1	0.991813	0.991813
AVERAGE	1.003369	1.000185	1.082929	1.089205

Table 5.19: Estimated Results of Simultaneous Equation Model: The Case of Productivity Equation in case of Rice

Variable	Coefficient	t-Statistic	Prob.
C	-6.6579	-1.49765	0.135
RF	0.41239*	3.437874	0
RF*RF	-0.02505*	-6.17996	0
HYV	0.263853*	4.297352	0
HYV*PI	-0.16199*	-5.48203	0
PI	0.020987*	4.20818	0
AL	0.129943*	7.350984	0
RL	0.005873*	6.309353	0
E	0.015796*	5.429152	0
G	-0.04246*	-3.42833	0
G*G	0.007155*	6.338846	0
AL*PI	0.070025*	2.295733	0.0222
Adjusted R-squared	0.933133		
F-statistic	265.6571*		
Prob(F-statistic)	0		

***significant at 1%, **significant at 5%, ***significant at 10%**

Table 5.20: Estimated Results of Simultaneous Equation Model: The Case of HYV Equation in case of Rice

Variable	Coefficient	t-Statistic	Prob.
C	-0.72672	-0.9481	0.3436
Pro	1.813622	19.82402	0
Pro * Pro	-0.6095	-10.4212	0
PI	0.202868	6.714106	0
AL	0.194761	10.17228	0
E	0.001346	7.717426	0
RL	0.006014	25.04043	0
DE	-0.37488	-18.3889	0
DS	-0.21779	-17.2172	0
Adjusted R-squared	0.817076		
F-statistic	218.8783		
Prob(F-statistic)	0		

***significant at 1%, **significant at 5%, ***significant at 10%**

Table 5.21: Marginal Effects of the Explanatory Variables from the Simultaneous Equation Model: The Case of Productivity Equation in case of Rice

RF	0.056669
HYV	0.34306
PI	0.018194
AL	0.095704
E	0.015796
RL	0.005873
G	-0.05173

Table 5.22: Wald Statistics of the Simultaneous Equation Model: The Case of Productivity Equation in case of Rice

	RF	HYV	PI	AL
F-statistic	84.90878*	14.73818*	94.79839*	9.517152*
Chi-square	339.6351*	29.47637*	284.3952*	19.0343*

***significant at 1%, **significant at 5%, ***significant at 10%**

Table 5.23: Marginal Effects of the Explanatory Variables from the Simultaneous Equation Model: The Case of HYV Equation in case of Rice

Pro	0.576607
PI	0.202868
AL	0.194761
E	0.001346
RL	0.006014

Table 5.24: Wald Statistics of the Simultaneous Equation Model: The Case of HYV Equation in case of Rice

	Pro
F-statistic	7.786664*
Chi-square	15.57333*

***significant at 1%, **significant at 5%, ***significant at 10%**

Table 5.25: Estimated Results of Simultaneous Equation Model: The Case of Productivity Equation in case of Wheat

Variable	**Coefficient**	**t-Statistic**	**Prob.**
C	2.64741*	15.31268	0
RF	0.57268*	16.91372	0
RF*RF	-0.01425*	-5.59468	0
HYV	0.94576*	5.050518	0
HYV*HYV	-0.01559*	-9.11478	0
GI	0.080711*	5.282306	0
AL	0.080246*	4.043884	0
E	0.442672*	6.039322	0
RL	0.004089*	4.735349	0
G	-0.02005*	-10.2495	0
G*G	0.001945*	6.597693	0
Adjusted R-squared	0.986863		
F-statistic	244.0788*		
Prob(F-statistic)	0		

***significant at 1%, **significant at 5%, ***significant at 10%**

Table 5.26: Estimated Results of Simultaneous Equation Model: The Case of HYV Equation in case of Wheat

Variable	Coefficient	t-Statistic	Prob.
C	-9.9125	-0.57325	0.567
Pro	2.28704*	8.275702	0
Pro* Pro	-0.99327*	-4.68481	0
GI	0.105491**	2.175052	0.0307
AL	0.110797*	4.73986	0
E	0.03243*	6.060085	0
RL	0.002145*	3.909765	0
DW	-0.51222*	-13.1495	0
DE	-0.06224**	-2.16364	0.0315
Adjusted R-squared	0.962316		
F-statistic	555.8371*		
Prob(F-statistic)	0		

*significant at 1%, **significant at 5%, ***significant at 10%

Table 5.27: Marginal Effects of the Explanatory Variables from the Simultaneous Equation Model: The Case of Productivity Equation in case of Wheat

RF	0.38141
HYV	0.969583
GI	0.080711
AL	0.080246
E	0.442672
RL	0.004089
G	-0.02408

Table 5.28: Wald Statistics of the Simultaneous Equation Model: The Case of Productivity Equation in case of Wheat

	RF	HYV	G
F-statistic	5.927216*	31.85528*	29.9528*
Chi-square	11.85443*	63.71057*	71.90559*

*significant at 1%, **significant at 5%, ***significant at 10%

Table 5.29: Marginal Effects of the Explanatory Variables from the Simultaneous Equation Model: The Case of HYV Equation in case of Wheat

Pro	0.276227
GI	0.105491
AL	0.110797
E	0.03243
RL	0.002145

Table 5.30: Wald Statistics of the Simultaneous Equation Model: The Case of HYV Equation in case of Wheat

	Pro
F-statistic	11.74023*
Chi-square	35.2207*

***significant at 1%, **significant at 5%, ***significant at 10%**

Table 5.31: Estimated Results of Simultaneous Equation Model: The Case of Productivity Equation in case of Jowar

Variable	**Coefficient**	**t-Statistic**	**Prob.**
C	1.220435	1.409591	0.8769
RF	0.524222*	16.82572	0
RF*RF	-0.0128*	-7.59024	0
HYV	0.312301*	16.74752	0
HYV*HYV	-0.10447*	-3.32291	0.0004
GI	0.040238***	2.011457	0.0408
AL	0.010107*	3.362723	0.0005
E	0.038582*	6.29684	0
G	-0.12801*	-5.94601	0
G*G	0.020968*	5.1892	0
Adjusted R-squared	0.940218		
F-statistic	218.5283*		
Prob(F-statistic)	0		

***significant at 1%, **significant at 5%, ***significant at 10%**

Table 5.32: Estimated Results of Simultaneous Equation Model: The Case of HYV Equation in case of Jowar

Variable	Coefficient	t-Statistic	Prob.
C	5.630868**	2.29402	0.0229
Pro	2.20192*	3.74501	0.0002
Pro * Pro	-0.97384*	-3.51964	0.0005
GI	0.859745*	10.6769	0
AL	0.266708*	8.744878	0
E	0.163257*	6.252307	0
RL	0.467455*	16.89942	0
DS	-0.55173*	-12.4611	0
DW	-0.41563*	-6.3259	0
Adjusted R-squared	0.759849		
F-statistic	105.9406*		
Prob(F-statistic)	0		

***significant at 1%, **significant at 5%, ***significant at 10%**

Table 5.33: Marginal Effects of the Explanatory Variables from the Simultaneous Equation Model: The Case of Productivity Equation in case of Jowar

RF	0.350195
HYV	0.476887
GI	0.040238
AL	0.010107
E	0.038582
G	-0.16573

Table 5.34: Wald Statistics of the Simultaneous Equation Model: The Case of Productivity Equation in case of Jowar

	RF	HYV	G
F-statistic	8.800815*	5.210642*	2.764926***
Chi-square	17.60163*	10.42128*	5.529851****

***significant at 1%, **significant at 5%, ***significant at 10%**

Table 5.35: Marginal Effects of the Explanatory Variables from the Simultaneous Equation Model: The Case of HYV Equation in case of Jowar

Pro	0.123118
GI	0.859745
AL	0.266708
E	0.163257
RL	0.467455

Table 5.36: Wald Statistics of the Simultaneous Equation Model: The Case of HYV Equation in case of Jowar

	Pro
F-statistic	39.45929*
Chi-square	78.91859*

***significant at 1%, **significant at 5%, ***significant at 10%**

Chapter 6

Comparison of Growth of output, Volatility and Total Factor Productivity Growth in Indian Agricultural Sector

6.1 Introduction

A detailed analysis regarding Growth, Volatility and Total Factor Productivity Growth (TFPG) of different crops in Indian Agricultural Sector has been made in the earlier chapters. The present chapter is involved in looking at the comparison of the crops and states in terms of the three performance indicators such as Growth of output, Volatility and Total Factor Productivity Growth (TFPG) of Indian Agricultural Sector.

After crop-wise analysis of the growth of output, Volatility and TFPG of Indian Agricultural Sector in chapters 3, 4 and 5 respectively, one may be interested in knowing that what is the relative position of the major selected crops and states with respect to their growth of output, volatility and TFPG? At the same time the factors affecting the growth of output and TFPG is a matter of much concern.

Thus the objectives of the present chapter are (i) to classify the major crops on the basis of their performance in terms of the three indicators such as rate of growth of output, volatility and TFPG(ii) to classify the major states on the basis of their performance in terms of the three indicators such as growth of output, volatility and TFPG and (iii) to look at the common factors responsible for variation in Growth of Output and total factor productivity growth.

Rest of the chapter is organized as follows:

Section 6.2 discusses the methodology and results of Comparison between Growth of output, Volatility and TFPG. **Section 6.3** presents the methodology and results of Comparison between the Determinants of Growth of output and TFPG and some concluding remarks are made in **Section 6.4.**

6.2 Methodology and Results of Comparison between Growth of output, Volatility and TFPG

6.2.1 Methodology for Comparison between Growth of output, Volatility and TFPG

In **chapter 3**, the Growth of output of the 9 major selected crops and their corresponding major producing states were found out using the multiple structural breaks analysis suggested by Bai and Perron (1998 and 2003) and one time endogenous structural break of Sen (2003). The results from the multiple structural breaks analysis suggests that there exists a strong regional variation among the states in terms of multiple breaks but any change of policy by the central government or state government may affect the crop production as a whole. From the results of Amit Sen (2003) method one can classify the crops and states into three major categories. (1) Good Performer, (2) Moderate Performer and (3) Bad Performer as described in Chapter-3 (see Table-3.19 of Chapter-3). The estimated results suggest that **(a)** none of the states are good performer for all crops. **(b)** the performance is **moderate** for the following states (i) AP, HA, BI, KA, MP, OR, PU, TN, UP and WB are in case of rice; (ii) In case of wheat BI, HA, PU and UP; (iii) For bajra, GU, HA, KA, MA, RA and UP; (iv) AP, GU, KA, MA, RA and UP for jowar; (v) In case of maize AP, BI, GU, HP, KA, MP, RA and UP; (vi) BI, HA, MA, MP, RA and UP in case of gram; (vii) AP, GU, HA, KA, PU and RA in case of cotton; (viii) for groundnut AP, GU, MP and TN and (ix) in case of rapeseed/mustard oil HA, MP, RA, UP and WB; and **(c)** the performance is **bad,** for the following states (i) AS in case of rice; (ii) MP and RA in case of wheat; (iii) TN in case of jowar; (iv) PU for maize; (v) in case of cotton MP and MA; (vi) KA for groundnut; (vii) AS and GU in case of rapeseed/mustard oil.

From chapter 4, the presence of volatility in growth of price can be measured by applying ARCH effect test and if one found any presence of ARCH effect in the series then one can estimate this ARCH effect by applying ARCH/GARCH method. Now from the results of the ARCH test it can be concluded that ARCH effects are present in all the selected nine crops. If one is interested in state-wise analysis then it can be said that ARCH effect or volatility is present in the following states and crops: **Food Crops: Rice:** AP, KA, OR, PU, UP and WB; **Wheat:** BI, HA and UP; **Jowar:** GU, TN and UP; **Bajra:** AP, HA, KA, MA, RA, TN and UP; **Maize:** GU, HP, MP, PU, RA and UP; **Gram:** BI, MP, MA, PU, RA and UP**; Non Food Crops: Cotton:** AP and KA; **Groundnut:** AP, GU, KA and TN; **Rapeseed/Mustard Oil:** HA, UP and

WB. From the results of the GARCH estimation after incorporating the variety it can be concluded that Coarse and Hamsalu variety of rice generates more return as well as volatility in the growth of output price in case of AP and Fine and Coarse for KA. For OR and PU, Fine and Coarse and Fine and Basmati variety of rice gives more return and affect volatility in positive direction. In case of WB, coarse variety of rice generates more return as well as volatility in the growth of output. Under Wheat, different varieties like White, Dara and White and Imported generates higher return and volatility for BI, HA and UP respectively. In case of Jowar Yellow, Red and White variety gives more return and more volatility for GU, TN and UP respectively. In case of Bajra Local and Superior variety of Bajra generates more return as well as volatility in the growth of output price for AP and KA respectively. Whereas for HA, Coarse and Desi variety gives more return and higher volatility. In case of RA local and Small are the main varieties which positively affect the volatility and give more return. In case of RA, Local and Small generates more return as well as volatility. In case of Maize Yellow, White and Coarse variety of maize gives more volatility and return for GU, MP and PU respectively. In case of RA, Local, Red and Coarse variety of maize did the same thing. Under Gram it can be concluded that Desi variety of gram gives more return as well as volatility for MP and PU. For RA, the determining variety which gives more return and volatility is FAQ. Under Cotton, Laxmi variety generates more return as well as volatility in the growth of output price for AP and KA. On the other hand Pods and Shell gives higher return and more volatility for AP and GU under Groundnut. Lastly, under Rapeseed/ Mustard Oil, Lahi and Laha for UP and Yellow, Fresh and Desi for WB generates more return as well as volatility in the growth of output price of Rapeseed/ Mustard Oil.

Thus, from the results of the GRACH estimation it can be concluded that the nature of volatility varies from crop to crop and state to state because uniform GARCH model is not the best fitted model for all crops. Not only this, the best fitted GARCH model varies across the states under a particular crop also. This implies that the nature of volatility varies state to state under a particular crop also.

Chapter 5 deals with the estimation of TFPG by using Biennial Malmquist Index (BMI) of non-parametric method of Data Envelopment Analysis (DEA). But due to unavailability of state-wise data one can estimate the TFPG only in case of three crops namely rice, wheat and jowar.

Among these three crops, overall TFPG is higher for Wheat (1.009686) followed by Rice (1.00856) and is lowest for Jowar (1.000418). In chapter-5 decomposition analysis has been incorporated to find out the sources of TFPG, i.e. to what extent the movement of TFPG has been contributed by efficiency changes, technology changes and scale efficiency changes. From the results of decomposition of Malmquist Index it can be concluded that scale changes are the most significant factor causing the productivity changes for all the three crops. Among the two other alternative sources of TFPG, efficiency change dominates over technical changes in case of rice, but in case of wheat the reverse is true. For jowar no such conclusion can be made regarding the dominance of the technical changes over the efficiency changes or vice-versa. In case of rice the improvement in the technical efficiency may push the states to a higher TFPG curve. In case of wheat, the superior technology is another factor for the improvement in the productivity. Apart from this, there exists a strong interstate variation behind the causes of the improvement in the productivity. Some sates experienced technological progress whereas some shows technological regress during the same sub period. Also the decadal performance of a particular state varies in terms of the relative movement of technological changes and efficiency changes. It is found that states experiencing technological progress in some decade face technological regress in the other decade. Same thing happened in case of change in the technical efficiency as well. In case of change in the scale most of the states experienced an improvement in the scale for most of the decade.

Since TFPG analysis can be done only with respect to three crops Rice, Wheat and Jowar, the comparison of the performance with respect to output growth, volatility and TFPG has been done for three crops only.

For the rest of the six crops Maize, Gram, Bajra, Cotton, Groundnuts and Rapeseed/Mustard Oil, performance analysis are judged with respect to growth of output and volatility.

The comparison analysis has been performed both state wise as well as crop wise.

In case of growth of output the performance of the states as obtained from the results of Sen (2003) will be considered for the comparison. The presence of the volatility can be obtained from the results of the ARCH test. In case of TFPG the mean value of TFPG for any particular crop for any state over the entire sample period is compared with respect to the grand mean of that particular crop over all sample period and all states. Then the 9 major crops and their corresponding major producing states on the basis of their performance based on these three indicators or two indicators whichever is applicable are classified into different groups defined below:

Thus on the basis of the performance with respect to output growth, extent of volatility and TFPG the criteria for comparison of Rice, Wheat and Jowar are specified as follows:

Good Performer:

- Performance in respect of growth of output is good (based on the criterion defined in Chapter-3), Absence of volatility in the growth of price series and having above average[1] TFPG.

Moderate Performer:

- Performance in respect of growth of output is moderate (based on the criterion defined in Chapter-3), Absence of volatility in the growth of price series and having above average TFPG.

Poor Performer:

- Performance in respect of growth of output is moderate, Absence of volatility in the growth of price series and having below average TFPG.

Or

- Performance in respect of growth of output is moderate, Presence of volatility in the growth of price series and having above average TFPG.

Or

- Performance in respect of growth of output is moderate, Presence of volatility in the growth of price series and having below average TFPG.

[1] We have calculated the mean average of the TFPG for the sample states and sample period. This is the grand mean of TFPG. Grand Mean is the mean over the entire sample period and all sample states for a particular crop. Now for those states whose mean TFPG over the sample period is above (below) the grand mean that state is called as the TFPG is above (below) the average.

Or

- Performance in respect of growth of output is bad (based on the criterion defined in Chapter-3), Absence of volatility in the growth of price series and having above average TFPG.

  Or

- Performance in respect of growth of output is bad, Absence of volatility in the growth of price series and having below average TFPG.

  Or

- Performance in respect of growth of output is bad, Presence of volatility in the growth of price series and having above average TFPG.

  Or

- Performance in respect of growth of output is bad, Presence of volatility in the growth of price series and having below average TFPG.

For rest of the six crops like Bajra, Maize, Gram, Cotton, Groundnut and Rapeseed / Mustard Oil on the basis of the performance with respect to output growth and extent of volatility the criteria for the comparison are specified as below:

Good Performer:

- Performance in respect of growth of output is good (based on the criterion defined in Chapter-3) and Absence of volatility in the growth of price series.

Moderate Performer:

- Performance in respect of growth of output is moderate (based on the criterion defined in Chapter-3) and Absence of volatility in the growth of price series.

Poor Performer:

- Performance in respect of growth of output is moderate and Presence of volatility in the growth of price series.

  Or

- Performance in respect of growth of output is bad (based on the criterion defined in Chapter-3) and Presence of volatility in the growth of price series.

Or

- Performance in respect of growth of output is bad and Absence of volatility in the growth of price series.

6.2.2 Results of comparison between Growth of Output, Volatility and Total Factor Productivity in case of all Crops

All the results are presented in Table 6.1 to 6.12.

The results of comparison between Growth of Output, Volatility and Total Factor Productivity in case of all Crops are presented in Table-6.1. The results suggest that the growth performances of all the crops are moderate but volatility is present in the growth of output price series for all the crops. In terms of TFPG the analysis is done only in case of rice, wheat and jowar. The TFPG has increased in case of all three crops. Now by comparing the results of growth, volatility and productivity it can be concluded that the overall performances of all the crops are poor.

6.2.3 Results of State-wise Comparison between Growth of Output, Volatility and Total Factor Productivity in case of Rice, Wheat and Jowar

All the results of comparison between growth of output, volatility and total factor productivity growth in case of rice, wheat and jowar are presented in the Table 6.2, 6.3 and 6.4 for rice, wheat and jowar respectively. Now from the results it can be concluded that

In case of Rice:

Good Performer: Nil

Moderate Performer: BI, HA and MP

Poor Performer: AP, AS, KA, OR, PU, TN, UP and WB

In case of Wheat:

Good Performer: Nil

Moderate Performer: Nil

Poor Performer: BI, HA, MP, RA, PU and UP

In case of Jowar:

Good Performer: Nil

Moderate Performer: AP and MA

Poor Performer: GU, KA, RA, UP and TN

6.2.4 Results of State-wise Comparison between Growth of Output and Volatility in case of rest of Six Crops

All the results of comparison between growth of output and volatility in case of rest of six crops i.e. (for Bajra, Maize, Gram, Cotton, Groundnut and rapeseed/mustard oil) are presented in Table 6.4 to 6.9 respectively. Now from the results of analysis it can be concluded that

In case of Bajra:

Good Performer: Nil

Moderate Performer: GU

Poor Performer: AP, HA, KA, MA, RA, TN and UP

In case of Maize:

Good Performer: Nil

Moderate Performer: AP, BI and KA

Poor Performer: GU, HP, MP, PU, RA and UP

In case of Gram:

Good Performer: Nil

Moderate Performer: HA

Poor Performer: BI, MP, MA, PU, RA and UP

In case of Cotton:

Good Performer: Nil

Moderate Performer: GU, HA, PU and RA

Poor Performer: AP, KA, MP and MA

In case of Groundnut

Good Performer: Nil

Moderate Performer: MP

Poor Performer: AP, GU, KA and TN

In case of Rapeseed/Mustard Oil:

Good Performer: Nil

Moderate Performer: MP and RA

Poor Performer: AS, GU, HA, UP and WB

Table 6.11 represents the results of state-wise performance in the agricultural sector. The performance of each state is determined as follows: for example AP is found to be the major producing states in case of Rice, Jowar, Maize, Cotton and Groundnut. Now, if the performance of AP for majority of the crops is good (moderate or poor), then it can be concluded that AP is the good (moderate or poor) performing state. In this context one can point out that for determining the overall performance of that states the share of different crops in the total agricultural production of that particular state is also important. For example in in the context of the present sample, for HA, among the six included crops Rice, Wheat, Gram, Bajra, Cotton and Rapeseed/ Mustard Oil, the performance is moderate in case of rice, gram and cotton but the performance is bad in case of wheat, bajra and Rapeseed/Mustard Oil. But it turned out that the combined share of rice, gram and cotton is greater than the combined share of wheat, bajra and Rapeseed/Mustard Oil. So it follows that the overall performance of HA is moderate. Now the results of Table 6.11 suggest that

Good Performing States: Nil

Moderate Performing States: HA

Bad Performing States: AP, AS, BI, GU, HP, KA, MA, MP, OR, PU, RA, TN, UP and WB

Now by considering all the results it can be concluded that under each crop performance of most of the states is bad. In other words, for these states either performance of growth is bad or there exists volatility in the price series or the TFPG is low. Only for few states the performance is moderate. That is the growth performance is moderate and there exists no volatility in the price series and the total factor productivity growth is above average. If one considers the state-wise performance the picture is almost same. Only for one state out of fifteen the performance is moderate. So the major problems in the Indian agricultural sector are that:

- Moderate or bad performance with respect to growth of output
- Low total factor productivity growth
- There exists volatility in the price series for all the selected crops.

6.3 Methodology and Results of Comparison between the Determinants of Growth of output and Total Factor Productivity Growth

6.3.1 Methodology for Comparison between the Determinants of Growth of output and Total Factor Productivity Growth

Looking at the factors responsible for variation in Growth of Output and TFPG from the results of chapter 3 and 5, the common factors can be identified which can boost up or hinder the performance of Indian Agricultural Sector.

6.3.2 Results of Comparison between the Determinants of Growth of output and Total Factor Productivity Growth

The results of common factors that increase the growth of output and TFPG in Indian agricultural sector are presented in Table 6.12. From the results it can be concluded that there exists a positive relation between growth of output or TFPG with the variables HYV uses, government irrigation or private irrigation, rainfall, government expenditure on agricultural education, research and extension, rural literacy and agricultural loan. Whereas distribution of operational land holding is negatively related with growth of output or total factor productivity growth. Now from the results of the determinants analysis of growth of output and TFPG it can be concluded that too much rainfall is bad for growth of output and total factor productivity growth. On the other hand the availability of agricultural loan, government irrigation or private irrigation, government expenditure on agricultural education, research and extension and rural literacy may boosts up the growth of output and TFPG in Indian agriculture.

So in order to overcome the major problems relating to growth and TFPG ofh the Indian agricultural sector the availability of agricultural loan, area under government irrigation or private irrigation, government expenditure on agricultural education, research, and extension and rural literacy has to be increased. On the other hand although rainfall and HYV uses may increase the growth of output and TFPG the dependency on these two explanatory variables has to be controlled. Similarly the inequality in the distribution of operational land holding has to be reduced in order to increase the growth of output and total factor productivity growth.

A comparison of the factors that stimulates growth and TFPG reveals that either government irrigation or private irrigation, government expenditure on agricultural education, research and extension, rural literacy and agricultural loan are common to both output growth and TFPG assigning some kind of a double role to these variables. Thus these variables are crucially important in enhancing growth and TFPG of the concerned output of the relevant states.

6.4 Conclusion

The Results on Growth of output, Volatility and TFPG of the major selected crops suggests that:

First of all, under each crop performance of most of the states is bad implying that for these states either performance of growth is bad or there exists volatility in the price series or the total factor productivity growth is low. Only for few states the performance is moderate because for these states the growth performance is moderate and there exists no volatility in the price series and the total factor productivity growth is above average. **Secondly,** the state-wise performance shows that only for one state the performance is moderate. Thus the major problems associated with the Indian agricultural sector are (i) moderate or bad performance in respect of growth of output, (ii) low TFPG and (iii) there exists volatility in the price series for some of the states. **Finally,** the results of common factors that boosts up the growth of output and TFPG in Indian agricultural sector indicates that in order to overcome the major problems related to Indian agricultural sector the availability of agricultural loan, area under government irrigation or private irrigation, government expenditure on agricultural education, research, and extension and rural literacy has to be increased. On the other hand the inequality, in the distribution of operational land holding has to be decreased in order to increase the growth of output and total factor productivity growth. Among these variables crucially important variables are government irrigation or private irrigation, government expenditure on agricultural education, research and extension, rural literacy and agricultural loan since they can promote both growth of output and TFPG.

Thus the analysis reveals that in order to foster both the growth and TFPG of Indian Agricultural Sector, any policy changes that will lead to increase in availability of agricultural loan, government irrigation or private irrigation, government expenditure on agricultural education, research and extension and rural literacy should be emphasized. Likewise policy changes leading to decrease in the inequality in the distribution of operational land holding will help in promoting TFPG and growth of output.

Table 6.1: Crop-wise Comparison of Growth, Volatility and Productivity

Crops	GROWTH	VOLATILITY	PRODUCTIVITY	PERFORMANCE
Rice	Moderate	Present	Increased	Poor
Wheat	Moderate	Present	Increased	Poor
Jowar	Moderate	Present	Increased	Poor
Bajra	Moderate	Present	Not Analyzed	Poor
Maize	Moderate	Present	Not Analyzed	Poor
Gram	Moderate	Present	Not Analyzed	Poor
Cotton	Moderate	Present	Not Analyzed	Poor
Groundnut	Moderate	Present	Not Analyzed	Poor
Rapeseed/Mustard Oil	Moderate	Present	Not Analyzed	Poor

Table 6.2: State-wise Comparison of Growth, Volatility and Productivity of Rice

STATES	GROWTH	VOLATILITY	PRODUCTIVITY	PERFORMANCE
AP	Moderate	Present	Below Average	Poor
AS	Bad	Not Analyzed	Below Average	Poor
BI	Moderate	Not Analyzed	Above Average	Moderate
HA	Moderate	Absent	Above Average	Moderate
KA	Moderate	Present	Above Average	Poor
MP	Moderate	Absent	Above Average	Moderate
OR	Moderate	Present	Above Average	Poor
PU	Moderate	Present	Below Average	Poor
TN	Moderate	Absent	Below Average	Poor
UP	Moderate	Present	Below Average	Poor
WB	Moderate	Present	Below Average	Poor

Table 6.3: State-wise Comparison of Growth, Volatility and Productivity of Wheat

STATES	GROWTH	VOLATILITY	PRODUCTIVITY	PERFORMANCE
BI	Moderate	Present	Above Average	Poor
HA	Moderate	Present	Below Average	Poor
MP	Bad	Absent	Above Average	Poor
RA	Bad	Absent	Above Average	Poor
PU	Moderate	Absent	Below Average	Poor
UP	Moderate	Present	Below Average	Poor

Table 6.4: State-wise Comparison of Growth, Volatility and Productivity of Jowar

STATES	GROWTH	VOLATILITY	PRODUCTIVITY	PERFORMANCE
AP	Moderate	Absent	Above Average	Moderate
GU	Moderate	Present	Not Analyzed	Poor
KA	Moderate	Absent	Below Average	Poor
MA	Moderate	Not Analyzed	Above Average	Moderate
RA	Moderate	Not Analyzed	Below Average	Poor
TN	Bad	Present	Above Average	Poor
UP	Moderate	Present	Not Analyzed	Poor

Table 6.5: State-wise Comparison of Growth, Volatility and Productivity of Bajra

STATES	GROWTH	VOLATILITY	PERFORMANCE
AP	Not Analyzed	Present	Poor
GU	Moderate	Absent	Moderate
HA	Moderate	Present	Poor
KA	Moderate	Present	Poor
MA	Moderate	Present	Poor
RA	Moderate	Present	Poor
TN	Not Analyzed	Present	Poor
UP	Moderate	Present	Poor

Table 6.6: State-wise Comparison of Growth, Volatility and Productivity of Maize

STATES	GROWTH	VOLATILITY	PERFORMANCE
AP	Moderate	Absent	Moderate
BI	Moderate	Absent	Moderate
GU	Moderate	Present	Poor
HP	Moderate	Present	Poor
KA	Moderate	Absent	Moderate
MP	Moderate	Present	Poor
PU	Bad	Present	Poor
UP	Moderate	Present	Poor
RA	Moderate	Present	Poor

Table 6.7: State-wise Comparison of Growth, Volatility and Productivity of Gram

STATES	GROWTH	VOLATILITY	PERFORMANCE
BI	Moderate	Present	Poor
HA	Moderate	Not Analyzed	Moderate
MP	Moderate	Present	Poor
MA	Moderate	Present	Poor
PU	Not Analyzed	Present	Poor
RA	Moderate	Present	Poor
UP	Moderate	Present	Poor

Table 6.8: State-wise Comparison of Growth, Volatility and Productivity of Cotton

STATES	GROWTH	VOLATILITY	PERFORMANCE
AP	Moderate	Present	Poor
GU	Moderate	Not Analyzed	Moderate
HA	Moderate	Not Analyzed	Moderate
KA	Moderate	Present	Poor
MP	Bad	Not Analyzed	Poor
MA	Bad	Not Analyzed	Poor
PU	Moderate	Absent	Moderate
RA	Moderate	Not Analyzed	Moderate

Table 6.9: State-wise Comparison of Growth, Volatility and Productivity of Groundnut

STATES	GROWTH	VOLATILITY	PERFORMANCE
AP	Moderate	Present	Poor
GU	Moderate	Present	Poor
KA	Bad	Present	Poor
MP	Moderate	Absent	Moderate
TN	Moderate	Present	Poor

Table 6.10: State-wise Comparison of Growth, Volatility and Productivity of Rapeseed/Mustard Oil

STATES	GROWTH	VOLATILITY	PERFORMANCE
AS	Bad	Not Analyzed	Poor
GU	Bad	Not Analyzed	Poor
HA	Moderate	Present	Poor
MP	Moderate	Not Analyzed	Moderate
RA	Moderate	Not Analyzed	Moderate
UP	Moderate	Present	Poor
WB	Moderate	Present	Poor

Table 6.11: State-Wise Performance of All Crops

State \ Crops	Rice	Wheat	Jowar	Bajra	Gram	Maize	Cotton	Groundnut	Rapeseed/ Mustard Oil	Over All
AP	P		M	P		M	P	P		P
AS	P								P	P
BI	M	P			P	M				P
GU			P	M		P	M	P	P	P
HA	M	P		P	M		M		P	M
HP						P				P
KA	P		P	P		M	P	P		P
MA			M	P	P		P			P
MP	M	P			P	P	P	M	M	P
OR	P									P
PU	P	P			P	P	M			P
TN	P		P	P				P		P
RA		P	P	P	P	P	M		M	P
UP	P	P	P	P	P	P			P	P
WB	P								P	P

M= Moderate, P= Poor

6.12 :Factors and their corresponding effects on the Growth of Output and TFPG

Variables	**Growth of Output**	**Total Factor Productivity Growth**
PI/GI	Positive	Positive
E	Positive	Positive
RL	Positive	Positive
AL	Positive	Positive
G	Negative	Negative

Chapter 7

Summary and Overall Conclusion

The present thesis analyzes three different aspects of Indian Agriculture **(i) growth pattern, (ii) extent of volatility in price of output** and **(iii) productivity** for different types of crops.

Considering **first problem** of the thesis it is necessary to check **first of all** whether the series of output of major selected crops and states converges to a path having trend preserving properties or not without the presence of structural break. The selected crops and major producing states are:

A. **Food crops:** Rice, Wheat, Maize, Jowar, Gram, Bajra.

For each of the crop we will consider the major states producing these crops and we have chosen those states and crops whose share in the total production are greater than or equals to 3%.

- ✓ Rice- Andhra Pradesh, Assam, Bihar, Haryana, Karnataka, Madhya Pradesh, Orissa, Punjab, Tamil Nadu, Uttar Pradesh, West Bengal
- ✓ Wheat- Bihar, Haryana, Madhya Pradesh, Rajasthan, Punjab, Uttar Pradesh
- ✓ Maize(Corn)- Andhra Pradesh, Bihar, Gujarat, Himachal Pradesh, Karnataka, Madhya Pradesh, Punjab, Uttar Pradesh, Rajasthan
- ✓ Jowar(Sorghum)- Andhra Pradesh, Gujarat, Karnataka, Maharashtra, Rajasthan, Tamil Nadu, Uttar Pradesh
- ✓ Gram- Bihar, Haryana, Madhya Pradesh, Maharashtra, Rajasthan, Uttar Pradesh
- ✓ Bajra(Peari Millets)- Gujarat, Haryana, Karnataka, Maharashtra, Rajasthan, Uttar Pradesh

B. **Cash crops or Non Food crops:** Cotton, Groundnuts, Rapeseed/Mustard Oil.

Again for each of the crops we will consider the major states producing those crops.

- ✓ Cotton- Andhra Pradesh, Gujarat, Haryana, Karnataka, Madhya Pradesh, Maharashtra, Punjab, Rajasthan
- ✓ Groundnuts- Andhra Pradesh, Gujarat, Karnataka, Madhya Pradesh, Tamil Nadu
- ✓ Rapeseed/Mustard- Assam, Gujarat, Haryana, Madhya Pradesh, Rajasthan, Uttar Pradesh, West Bengal

The study period is from 1970-71 to 2013-14.

Secondly, the present thesis is interested in testing whether the growth process converges to a path having trend preserving properties in the different series using Sen (2003) approach.

Thirdly, by Bai-Perron (1998 and 2003) method this thesis also tried to check the existence of any multiple structural breaks in the series or not.

Regarding growth pattern one can find most of existing literature are related to classical method using deterministic trend analysis [Sen, 1967; Narain, 1977; Rudra, 1982; Reddy, 1978; Das, 1978; Srinivasan, 1979; Vidyyanathan, 1980; Dandekar, 1980; Ray, 1983; Sawant, 1983; Dev, 1987; Boyce, 1987; Saha and Swaminathan, 1994; Sawant and Achuthan, 1995; Bhalla and Singh, 1997, etc] and there is dearth in the studies using the recent time series econometric method, although some literature are available [Mukhopadhyay and Sarkar, 2001; Oehmke and Schimmelpfennig,2004; Ghose and Pal ,2007; Hossain,2008; Sengupta, Ghosh and Pal ,2009; Pal and Ghose ,2012; Pal and Ghose ,2013; etc.].

A detailed crop wise study for the Indian Agriculture using this modern time series approach is still lacking. The present thesis intends to add the literature on this issue by estimating structural break and testing for convergence of different crops using modern time series approach. **In fact the analysis of structural break using Bai-Perrion or testing for convergence by Sen (2003) approach are in fact not much available in the literature.**

Finally, after the estimation of growth it is important to recognize the reasons behind the variation in growth of output. In the present study the determinants for growth has been found for all the crops included in the sample. Preferably while specifying output growth equation, one should keep in mind that output growth will depend on the input growth as well as the different infrastructural, institutional and demographic factors like growth of HYV uses, Government irrigation or Private irrigation, Rainfall, Government expenditure on agricultural education, research and extension, Rural literacy, Agricultural Loan and Inequality in Distribution of Land Holding. In the third problem while estimating the total factor productivity growth we have taken into account seeds, fertilizers, manure uses, human labour etc. collected from cost of cultivation data published by Government of India. These inputs data are available only for three crops: Rice, Wheat and Jowar for the major producing states of these crops. But as panel approach has been considered for each of the all 9 crops including all the major producing states and for entire time point we cannot include input as the determinant for crops other than Rice, Wheat and Jowar. For Rice, Wheat and Jowar we have incorporated both the growth of inputs like fertilizers (F), manure uses (M) and human labour (L)[1] as well as the explanatory variables as discussed above which include growth of HYV seeds. So, for these three crops Rice, Wheat and Jowar we have two sets of regression

I. Excluding the inputs
II. Including the inputs.

Among the chosen explanatory variables it is found that there exist some explanatory variables which in turn depends on the dependent variable, ie. growth of output. In the present case one of the explanatory variable considered for growth of output is the growth of HYV uses which in turn depends on the growth of output. Thus in order to explain the growth of output, one need to formulate a simultaneous equation kind of framework.

Again, Indian states with their uniqueness influence the growth and performance of different crops in several counts. Thus the growth and performance of different crops in different states do not always move in the same path. As we have considered different major producing states under each crop so for analyzing the determinant of growth rate we need to construct a panel model for each of the crop.

Thus in order to estimate the major determinants one need to construct a simultaneous kind of framework in the panel setup showing two way dependency between the dependent

[1] Animal labour is not included as the determinant because most of the entries under animal labour are zero or unavailable

variable and the explanatory variable. So, to get a comprehensive picture about the possible determinants influencing growth of output of different crops a simultaneous panel regression analysis has been used in order to find out major determinants of growth for the period 1970-71 to 2013-14.

While estimating the simultaneous panel regression, the problem of heterogeneity is tackled by considering a seemingly unrelated regression (SUR) framework, where each regression was adjusted for contemporaneous correlation (across units) and cross-section heteroscedasticity is adjusted by White Cross-Section. For regression purpose, both dependent variable and explanatory variables in growth terms have been considered. Also while estimating the panel model the Hausman test is used for testing whether fixed effect model is a better fitted one over the random effect model or not. The problem of identification has been checked and turned out to be over-identified. The use of simultaneous equation approach is not widely used in the literature for determinant analysis and hence the present thesis adds the literature in this context. **The whole study is presented in Chapter 3.**

Regarding the **second problem** of the present thesis, it can be mentioned that for measurement of volatility the earlier studies [Heady, 1952; Heady, 1961; Dandekar, 1976; Bliss and Stern, 1982; Rangaswamy, 1982; Sing and Nautiyal, 1986; Sankar and Mythili, 1987; Mosnier, Reynaud, Thomas, Lherm, Agabriel, 2009; etc.] are based on different specifications of model and estimation procedure but are devoid of the use of the modern time series technique. In fact, the perusal of the literature reveals that there is dearth in studies relating to the measurement of volatility in the agricultural sector by using modern time series approach like autoregressive conditional heteroscedasticity model (ARCH)/ generalized autoregressive conditional heteroscedastic model (GARCH) method and the present thesis attempts to contribute to the literature in this direction. Thus the **first objective** of this volatility issues is to check whether there is any ARCH effect in the series of the growth of price indices of major selected crops or not for the period 1970-71 to 2013-14. The major selected crops and states are already defined in first problem of the present thesis. After checking the ARCH effect **next objective** is to estimate the volatility of the series of the growth of price indices of the major selected crops by applying ARCH or GARCH method. **Thirdly**, it is important to check whether different variety of each crop has any effect on the volatility or not. For this purpose we have taken growth of price of different variety of each crop for each of their major producing states and capture the effect of variety on the volatility by incorporating dummy variables corresponding to the variety of each crop in basic equation defining price volatility. Further it is interesting to check whether these varieties give more return or not. **Chapter 4 carries out the whole study.**

Coming to the **third** problem of Total Factor Productivity Growth (TFPG), the most significant question is that whether productivity of these crops has increased or not. After the introduction of policies of economic reforms in 1991 the agricultural sector was affected indirectly by devaluation of exchange rate, liberalization of external trade and disprotection to industry. One of the major objectives of introducing these policies is to increase productivity. Natural question arises is that what is the extent of productivity for different crops. Some literature are available that measures productivity in Indian agriculture [Kumar and Rosegrant, 1994; Trueblood, 1996; Arnade, 1998; Fan, Hazell and Thorat, 1998; Murgai, 1999; Forstner et al, 2002; Bhushan, 2005; Bosworth and Collins, 2008; etc.]. Few of them adopted crop wise estimates by using Data Envelopment Analysis (DEA) and so there is dearth in the study relating to the crop wise analysis of productivity by using non parametric approach. The present thesis intends to take this into account.

So the **first objective** related to third problem is to find out the Total Factor Productivity Growth of different crops in Indian Agricultural sector for the period 1970-71 to 2013-14 by using Biennial Malmquist Index (BMI) of non-parametric method of Data Envelopment Analysis (DEA) and state level panel data. The selected crops and major producing states are as follows:

- ✓ Rice- Andhra Pradesh, Assam, Bihar, Haryana, Karnataka, Madhya Pradesh, Orissa, Punjab, Tamil Nadu, Uttar Pradesh, West Bengal
- ✓ Wheat- Bihar, Haryana, Madhya Pradesh, Rajasthan, Punjab, Uttar Pradesh
- ✓ Jowar(Sorghum)- Andhra Pradesh, Karnataka, Maharashtra, Rajasthan and Tamil Nadu.

After finding out the extent of TFPG, the **second objective** relating to this third problem of the thesis is to decompose TFPG into its different components: technical changes, efficiency changes and scale efficiency changes to check which component dominates over the other while finding out the major sources of TFPG.

After finding out the extent and sources of TFPG the **third objective** is to find out the factors explaining the productivity of the selected crops. To explain the factors behind variation in productivity this study considered different infrastructural, institutional, and demographic variables like growth of HYV uses, Government irrigation or Private irrigation, Rainfall, Government expenditure on agricultural education, research and extension, Rural literacy, Agricultural Loan and Inequality of Distribution of Land Holding as possible determinants of TFPG.

For estimation purpose it can be noted that TFPG is basically dependent on the growth of technology along with the other factors. In the context of agriculture one possible way is that the growth of technology can be represented by the growth of HYV uses. On the other hand, the growth of HYV uses in turn may be dependent on the TFPG itself with the other factors. Thus one can get a simultaneous kind of relationship between TFPG and growth of HYV uses. The present problem uses a simultaneous panel regression model for estimating the determinants of TFPG following the same methodology as described in first problem. **This is the subject matter of Chapter 5.**

Finally, an interstate comparison is made on the basis of growth of output, extent of volatility and productivity values. Also the common factors affecting growth of output and productivity are pointed out.

Regarding the data for growth analysis all the data has been collected from the different issues of the Statistical abstract, Agriculture at a Glance, Agriculture in Brief, Handbook of Statistics of Indian Economics, *www.indianstat.com* (an online commercial data service), Cost of Cultivation data published by the Government of India. In case of volatility analysis the month wise data on wholesale price indices of major selected crops from April 1982 to December 2013 has been collected from the website of the Office of the Economic Adviser in the Department of Industrial Policy and Promotion, Ministry of Commerce & Industry in different base period i.e. 1981-82, 1993-94 and 2004-05. The data on wholesale price indices of different crops from January 1980 to March 1982 has been collected from the Agricultural prices in India published by the Government of India in 1970-71 as base period. We have converted all the price indices in 1970-71 base period. The wholesale price indices of different crops from January 1970 to December 1979 are unavailable. The data on wholesale price for different variety of each crop and selected major producing states has been collected from the different issues of Agricultural prices in India published by the Government of India, Statistical Abstracts published by Central Statistical Organization (CSO) of India, *www.indianstat.com* (an online commercial data service), Agricultural Statistics at a Glance, and Agriculture in Brief published by the Central Statistical Organization and State Finance. Price data is unavailable for some major producing sates of different crops which are as follows: Rice: AS and BI; Jowar: MA and RA; Gram: HA; Maize: JK; Cotton: GU, HA, MP, MA and RA; Rapeseed/Mustard: AS, GU, MP and RA. Apart from this data of wholesale price is available for only one variety for different major producing states under different crops which are as follows: Rice: UP; Gram: BI, MA and UP; Bajra: MA; Maize: HP and UP; Groundnut: KA and TN; Rapeseed/Mustard: HA. Also wholesale price data for different variety are available from January 1970 to December 2006 in case of BI and HP and January 1970 to December 2009 in case of RA under Maize. In case of Cotton for MP and TN data is available from January 1970 to December 1999. Lastly, for productivity analysis we have considered the input and output data for estimating the productivity growth. The inputs and output are as follows: Output: Production of each Crop; Inputs: Seed (Kg.), Fertilizer (Kg. Nutrients), Manure (Qtl.), Area (‘000 Hectares), Human Labour (Man Hrs.). All these data has been collected from the different issues of the Statistical abstract, Agriculture at a Glance, Agriculture in Brief, Handbook of Statistics on Indian Economy, *www.indianstat.com* (an online commercial data service), Cost of Cultivation data published by the Government of India. Due to unavailability of state-wise cost of cultivation data from 1970-71 to 2013-14 for majority of the crops in this chapter we cannot made productivity analysis for majority of the crops. Perhaps in this chapter we are considering only three crops i.e. Rice, Wheat and Jowar. The major producing states of these crops are as follows: Rice- Andhra Pradesh, Assam, Bihar, Haryana, Karnataka, Madhya Pradesh, Orissa, Punjab, Tamil Nadu, Uttar Pradesh, West Bengal; Wheat-Bihar, Haryana, Madhya Pradesh, Rajasthan, Punjab, Uttar Pradesh; Jowar(Sorghum)- Andhra Pradesh, Karnataka, Maharashtra, Rajasthan and Tamil Nadu.

The concluding observations on the basis of the whole study are as follows:

Results on Growth

The results on the growth issue discussed in chapter 3 can be summarized as follows:

Results of Unit Root Test

First of all, from the results of unit root analysis it can concluded that for all the sample states in case of all the crops, the series are found to be stationary excepting rice for MP. So, the multiple structural break analysis cannot be done in case of MP for rice production.

Secondly the results of trend analysis suggests that in case of rice and wheat the ADF, PP and KPSS test suggest that there exist a significant positive trend for all the states which has stationary process. So, one can apply multiple structural break analysis[2] for all states in case of **Rice** and **Wheat** production except MP for Rice. In case of **Bajra** the underlying trend is positive and statistically significant for HA, MA, RA and UP. But in case of GU and KA the underlying trend is insignificant for ADF, PP and KPSS test. So, considering Bajra one can't apply the multiple structural break analysis for GU and KA. In case of **Gram** the underlying trend is negative and statistically significant for BI, RA and UP. In case of HA, MP and MA the underlying trend is positive and statistically significant. The deterministic trend is insignificant in case of MA and RA for **Jowar**. But this deterministic trend is negative and statistically significant in case of AP, GU, KA, TN and UP. In case of **Maize** the underlying trend is positive and statistically significant for all the states excepting PU. For PU the underlying trend is negative and significant. Thus, from the results of the trend analysis one can conclude that multiple structural break analysis is applicable for all the sample states in case of all food crops excepting GU and KA for Bajra, MP for rice and MA and RA in case of Jowar.

Now, among the cash crops the underlying trend is insignificant in case of MP for **Cotton** production. For rest of the states in case of cotton the underlying trend is positive and statistically significant. In case of **Groundnut** the underlying trend is significant and positive for GU only. For rest of the states the underlying trend is insignificant. In case of **Rapeseed/Mustard** Oil the

[2] Coming to the issue of multiple structural breaks, as is explained in Chapter-3, that in order to apply the multiple structural break test procedure it is needed that the data generating process should represent a significant trend stationary process.

underlying trend is negative and significant only in case of UP and for rest of the states the underlying trend is positive and statistically significant. So, in case of cash crops multiple structural break analysis is not applicable in case of MP for cotton and in case of AP, KA, MP and TN for Groundnut.

Thirdly, the results of Sen (2003) approach represent the fact that the nature of the series for all selected crops and states is converging to a trend. Now by analyzing the results of the break points it can be concluded that in case of **rice, cotton** and **groundnut** most break points occurs in the first half of the last decade i.e. 2000-2005. In case of **wheat, jowar,** and **Rapeseed/Mustard Oil** most break points occurs in the last half of the 70's decade. Also the effect of the introduction of liberalization policy after 1991 is prominent in case of **bajra** and **jowar**. In case of **maize** most of the break points occur in the decade of 80's. In case of **gram** no policy change can affect the growth of this crop.

Fourthly, comparing the growth performance of all crops following TS process, states are classified into different groups: (i) Group A (Good performer), (ii) Group B (Moderate performer) and (iii) Group C (Bad performer). The exact criterion for having a good performer, moderate performer and bad performer are explained in Chapter-3 (see Table-3.19). It is found that there is wide variation in growth of major selected crops across states which can be summed up as follows:

I. None of the states are good performer for all crops.

II. The performance is **moderate** for the following states (i) AP, HA, BI, KA, MP, OR, PU, TN, UP and WB in case of **rice**; (ii) In case of **wheat,** BI, HA, PU and UP; (iii) For **bajra**, GU, HA, KA, MA, RA and UP; (iv) AP, GU, KA, MA, RA and UP for **jowar**; (v) In case of **maize,** AP, BI, GU, HP, KA, MP, RA and UP; (vi) BI, HA, MA, MP, PU, RA and UP in case of **gram**; (vii) AP, GU, HA, KA, PU and RA in case of **cotton**; (viii) for **groundnut,** AP, GU, MP and TN; (ix) in case of **rapeseed/mustard oil** HA, MP, RA, UP and WB.

III. The performance is **bad,** for the following states (i) AS in case of **rice**; (ii) MP and RA in case of **wheat**; (iii) TN in case of **jowar**; (iv) PU for **maize;** (v) in case of **cotton,** MP and MA; (vi) KA for **groundnut**; (vii) AS and GU in case of **rapeseed/mustard oil**.

Fifthly, results of multiple structural break analysis suggest that in case of **rice** for all the states there exists at least one break in the deterministic trend which are significant at least at 5% level. Further the results suggest that in case of AP there exists three breaks in the series which occurs at 1984, 1991 and 2002. In case of AS the estimated break dates are 1990, 1998 and 2004. In case of BI and PU there exist two breaks in the deterministic trend which are 1994, 2004 and 1977, 1983 respectively. In case of TN, UP and WB there exist three breaks in the series and the estimated break dates are 1977, 1984 and 2002 in case of TN, 1978, 1988 and 2002 in case of UP and in case of WB the estimated break dates are 1982, 1987 and 2001. In case of HA and OR there exist four breaks in the deterministic trend of the series; for HA the breaks are 1976, 1987, 1993 and 2005, while for OR the corresponding breaks are 1977, 1983, 1996 and 2003. In case of KA there exists only one break in the series which occurs at 1995.

In case of **wheat,** there exist at least one break in the series for all the states. Again it can be concluded that there exist a strong interstate variation in terms of multiple structural breaks in case of wheat production. For example there exist four breaks in the series for HA, PU and UP whereas two numbers of breaks in case of BI and MP. There exist three numbers of breaks in case of RA.

There exist at least one break in the series for all the states for **Bajra**. There exist two numbers of breaks in case of HA, MA, RA and UP. But the dates of occurrence of the breaks differ from state to state.

According to the results of Bai-Perron there exist two breaks in the series for all the states except UP in case of **Gram**. In case of UP there exist three breaks in the series.

For **Jowar,** the results of multiple structural break analysis suggest that in case of KA there is no break in the series. In case of TN and UP there exist two breaks in the series. In case of AP there exist three breaks and for GU there exists one break in the series.

In case of **Maize,** there exist four breaks in the series for AP and PU. In case of GU, HP and KA there exist three breaks in the series whereas there exist two breaks in the series in case of BI, MP and RA. In case of UP there exists one break in the series for Maize production.

Now, among the cash crops in case of **cotton** there exist three breaks for AP. HA and MA. For GU, KA, PU and RA there exists one break in the series.

In case of **Groundnut** the multiple structural break analysis is applicable only in case of GU and there exists one break.

In case of **Rapeseed/Mustard Oil** there exist three breaks in the series for GU, MP, RA, UP and WB. For HA there exist two break in the series whereas in case of AS there exists one break in the series.

So, in the result of the multiple breaks analysis regional variation is very much prominent among the states and also among the crops.

Sixthly, by combining the results of multiple structural break and the results of one time endogenous structural break [Sen (2003)] it can be concluded that in case of **rice** the major breaks occur for AP, AS, BI, HA, KA, MP, OR, PU, TN, UP and WB at or between the years 2002-04, 2004-06, 2004-06, 1976, 1991-94, 2000, 2003-04, 1977-79, 2002-04, 1987-88 and 1982-83 respectively. For **wheat** major breaks are at or between 1985-87, 1975-78, 1993-95, 1975-77, 1996-98 and 1975-76 in case of BI, HA, MP, PU, RA and UP respectively. In case of **bajra**, for the states like GU, HA, KA, MA, RA and UP major breaks are 1991, 1991-94, 1976, 186-87, 1990-91 and 1991-92 respectively. The occurrence of major break year are 1986-88, 1983-86, 1976, 1976, 2006, 1991-92 and 1995-97 for the states AP, GU, KA, MA, RA, TN and UP respectively in case of **jowar**. In case of **maize** for the sates AP, BI, GU, HP, KA, MP, PU, RA and UP the major breaks comes out at or between the years 1980-84, 1991-94, 1987-89, 1983-86, 1989, 1981-84, 1988-90, 1986-89 and 1984-86 respectively. For **gram** major selected states are BI, HA, MP, MA, RA and UP and major breaks occur at 2001-02, 1999-2000, 1979-81, 1986-89, 1999-2000 and 1986-87 respectively.

Now, in case of **cotton** for the states AP, GU, HA, KA, MA, MP, PU and RA the major breaks are 1976-79, 1999-2003, 2004, 2005, 1993-95, 2004, 2000-04 and 1988-1990 respectively. For **groundnut** the major breaks are 1978, 2001-03, 1991, 1977 and 2006 for the states AP, GU, KA, MP and TN respectively. In case of **rapeseed/mustard oil** the major breaks occur at or between 1980-81, 1982-85, 1980-81, 1979-80, 1978-81, 1989-90 and 1978 for the states AS, GU, HA, MP, RA, UP and WB respectively.

Relevantly it can be mentioned that although the study of different food crops and cash crops supports the existence of multiple structural breaks, the earlier results of Sen (2003) analysis support the existence of a time series that produces converging trend for all the states and crops.

Lastly, the results of determinants analysis as applied to each of the crop suggests that in case of **rice** growth of output is positively, linearly and significantly related with growth of government irrigation and agricultural loan. Growth of output is significantly and non-linearly related with growth of rainfall and HYV uses. Also there exists non-linear relation between growth of output and government expenditure on agricultural research and extension and rural literacy. The interaction term between government expenditure on agricultural research and extension and rural literacy is positive implying that the effect of government expenditure on agricultural research and extension on growth of rice in turn is dependent on the rural literacy, on the other hand the effect of rural literacy on the growth of rice will depend on the growth of government expenditure on agricultural research and extension. On the other hand growth of rice is negatively and significantly related with inequality in operational land holding. In case of **wheat** the determinants of growth of output is almost same as in case of rice except government expenditure on agricultural research and extension and rural literacy. Here government expenditure on agricultural research and extension and rural literacy is positively and linearly related with growth of output. The growth of HYV uses, government irrigation, government expenditure on agricultural research and extension, agricultural loan and rural literacy has a significant positive effect on growth of output in case of wheat. In case of **bajra** the determinants of growth of output is same as in case of rice excepting that here growth of rainfall has another interaction term with government irrigation which is negative but statistically insignificant. For **gram** the growth of output is positively and significantly affected by the growth of rainfall, HYV uses, private irrigation, government expenditure on agricultural research and extension and agricultural loan. Among them growth of rainfall and growth of HYV uses is non linearly related to growth of gram. The relationship is inverted U shape. The major significant variables behind the growth of output in case of **jowar** are almost same as in case of gram excepting growth of rainfall. Here growth of rainfall is linearly related with growth of jowar. In case of **maize** the major influencing determinants behind the growth of maize are rainfall, HYV uses, private irrigation, government expenditure on agricultural research and extension, agricultural loan, rural literacy and inequality in operational land holding. Among these variables all have significant positive effect on growth of maize excepting operational land holding. Inequality in Operational land holding has a negative effect on growth of output.

Among the cash crops in case of **cotton** the results is similar as in case of gram. Only the government irrigation and agricultural loan has an interaction effect which is significant and positive on the growth of cotton suggesting that the effect of government irrigation on growth of cotton in turn is dependent on the supply of agricultural loan, on the other hand the effect of agricultural loan on the growth of cotton will depend on the availability of government irrigation. For **groundnut** there exists non-linear relation between the growth of groundnut and rainfall, HYV uses and inequality in operational land holding. On the other hand growth of groundnut is positively and linearly related with private irrigation, government expenditure on agricultural research and extension, agricultural loan and rural literacy. The major determinants for **rapeseed/mustard oil** are rainfall, HYV uses, private irrigation, government expenditure on agricultural research and extension, agricultural loan, rural literacy and inequality in operational land holding.

In case of **rice** the growth of HYV uses are significantly and positively affected by the growth of rice, government irrigation, agricultural loan, rural literacy and government expenditure on agricultural research and extension. The growth of rice and the growth of HYV uses have non linear relationship. The first polynomial of the growth of rice is positive and statistically significant while the second polynomial is negative and statistically significant implying that there exists a threshold limit beyond which growth of rice production may decrease the growth of HYV uses. The regional dummies of northern and southern region taking middle as base are positive and significant implying that growth of HYV uses is more in the northern and southern region than in the middle region. For **wheat** the determinants of HYV uses are almost same as in case of rice excepting the growth of private irrigation. The growth of private irrigation has positive and significant effect on growth of HYV uses. The major determinants of HYV uses in case of **bajra** are almost same as in case of rice and wheat excepting the regional dummies. The effect of northern region dummy is positive and significant whereas the effect of western region dummy is negative and statistically significant. Here southern region is taken as the base region because the share of southern region is minimum. In case of **gram** the growth of HYV uses are significantly and positively affected by the growth of gram, government irrigation, government expenditure on agricultural research and extension, agricultural loan and rural literacy. The coefficient of regional dummies suggests that northern region, western region and middle region uses more HYV than eastern region. In case of **jowar** there exists a non-linear relationship between growth of HYV uses and growth of jowar. In case of regional dummies the dummy for western region and southern region has negative and significant effect implying that growth of HYV uses is more in case of northern region than these two regions. For **maize** all the major determinants of growth of HYV uses are growth of maize, government irrigation, government expenditure on agricultural research and extension and rural literacy. From the sign of regional dummy it can be seen that eastern, western, middle and southern region uses less HYV than the northern region.

In case of **cotton,** the determinants of growth of HYV uses is same as in case of gram except the result of regional dummies and western region, northern region and southern region has positive and significant effect on growth of HYV uses. In case of **groundnut** the major determinants of the HYV uses are growth of groundnut, agricultural loan, government irrigation, rural literacy and government expenditure on agricultural research and extension. In case of **rapeseed/mustard oil** the determinants of the growth of HYV uses are growth of output, agricultural loan, rural literacy and government irrigation. Apart from this in case of rapeseed and mustard oil, eastern, northern and western region uses moe HYV than the middle region.

Now, if one consider input growth as the explanatory variable, then one may point out that even though there is a non linear relationship between growth of output and growth of labour, the marginal effect of growth of labour is positive implying that although there exists a positive relation between growth of output and growth of employment but after a limit growth of employment may hamper the growth of output. It is the common factor for all the three crops (Rice, Wheat and Jowar). Apart from this growth of fertilizer uses is another major determinant not only for the growth of output but also for the growth of HYV uses. On the other hand, growth of Government or Private irrigation, government expenditure on agricultural research and extension and rural literacy also have positive and significant effect on the growth of output. Again growth of HYV uses has a non linear effect on the growth of output but the marginal effect of growth of HYV uses is positive implying that if growth of HYV uses increases then growth of output also increases and this is the common feature of all the three crops.

Now in case of growth of HYV equation, growth of fertilizer uses is a significant explanatory variable. Growth of fertilizer has a positive effect on the growth of HYV uses for all the three crops. Again there exists a non linear inverted U shape relationship between growth of HYV uses and growth of output, but the marginal effect of the growth of output is positive implying that an increase in the growth of output may positively affect the growth of HYV uses and this is the common feature of all the three crops. Again for all the three crops, Government or Private irrigation, government expenditure on agricultural research and extension, rural literacy and Agricultural loan has a positive and significant effect on the growth of HYV uses.

Thus Government or Private irrigation, government expenditure on agricultural research and extension, rural literacy and Agricultural loan has positive effect on both growth of output as well as growth of HYV uses. There exists a simultaneous kind of relationship between growth of output and growth of HYV uses. The growth of HYV uses has a positive and significant effect on the growth of output and growth of output in turn positively and significantly affects the growth of HYV uses. Thus the explanatory variables like Government or Private irrigation, government expenditure on agricultural research and extension, rural literacy and Agricultural loan may get the greater importance in the policy suggestion because these variables affect the growth of HYV uses which in turn may push up the growth of output.

So, an interesting observation is that in order to foster growth, any policy changes that will lead to increase in the availability of agricultural loan, government and private irrigation rural literacy, government expenditure on agricultural research and extension should be emphasized. Again the policy of land reform should be implemented effectively so that targeted growth rate may be achieved.

Results on Volatility

Chapter 4 of the present thesis is concerned with the extent of volatility. We have estimated the extent of volatility of each crops considering the major producing states.

The results on the extent of volatility discussed in chapter 4 can be summarized as follows:

For Individual Crops

First of all, in case of all selected crops the results of ADF, PP and KPSS statistics suggest that the growth rate of price index series for all crops are stationary at 1% level.

Secondly, the results of testing of ARCH effect suggest that ARCH effects are present in the growth of price series for all selected crops. Chi-square statistics are significant at 1% level in case of Rice, Wheat, Bajra, Gram, Cotton, groundnut and Rapeseed/Mustard Oil and at 5% level for Jowar and Maize. So, it can be concluded that for all the crops current period volatility is affected by the previous period's volatility.

Thirdly, the GARCH estimation suggests that a uniform model for volatility is not applicable for each crop. In case of Rice, Jowar, Maize and Rapeseed/Mustard Oil GARCH (2, 1) model is appropriate model implying that current period volatility depends upon the randomness of past two periods and also on the volatility of the past period. In case of Gram and Cotton, GARCH (2, 2) model is most suitable model implying that current period volatility depends upon the randomness of past two periods and also on the volatility of the past two periods and for Wheat and Groundnut GARCH (1, 2) model is the best fitted model implying that implying that current period volatility depends upon the randomness of past period and also on the volatility of the past two periods. In case of Bajra GARCH (1, 1) model is the suitable one and the implication is same as above. So, it can be concluded that for all crops current period volatility is not only affected by the volatility of previous months but also by the volatility of previous month's randomness.

In Case of each state under each crop by taking different variety:

First of all, the results of ADF, PP and KPSS statistics suggest that the growth rate of price series are stationary at 1% level for all crops and states except KPSS statistic for HA in case of wheat and KA in case of groundnut. The KPSS statistics for both HA and KA is significant at 5% level.

Secondly, the results of testing the presence of ARCH effect imply that ARCH effects are present for the following states under each crop: i) Rice: AP, KA, OR, PU, UP and WB; ii) Wheat: BI, HA and UP; iii) Jowar: GU, TN and UP; iv) Bajra: AP, HA, KA, MA, RA, TN and UP; v) Maize: GU, HP, MP, PU, RA and UP; vi) Gram: BI, MP, MA, PU, RA and UP; vii) Cotton: AP and KA; viii) Groundnut: AP, GU, KA and TN and ix) Rapeseed/Mustard Oil: HA, UP and WB.

Lastly, the results of GARCH estimation suggest that the extent of volatility differs among different crops and for different states. In case of Rice for AP coarse and hamsalu variety has more positive and significant effect on the volatility than akkalu. For KA fine and coarse variety has more significant and positive effect on volatility of growth of output price. In case of OR fine and coarse and in case of PU fine and basmati has significant and positive effect on the volatility of the growth of price of rice. In case of UP, we cannot analyze the effect of the variety on the volatility of the growth of price of rice because in this state there is only one variety of rice i.e. coarse-III. Thus for UP we have estimated EGARCH (p,q), ARCH (p,q) and GARCH (p,q) model without dummy variable and found that EGARCH (1,1) model is the best fitted one. Again coarse has more significant and positive effect on the volatility of growth of price than common in case of WB. For wheat in case of BI growth of price of white variety of wheat is more volatile than FAQ. Similarly, growth of price of dara is more volatile than Mexican variety of wheat in case of HA. Lastly, in case of UP, white and imported variety is more volatile than dara. In case of jowar, the growth of price of jowar in case of GU is more volatile for yellow variety than white. In case of TN, red variety is more volatile whereas in case of UP white variety is more volatile. For bajra, in case of AP the growth of price for local variety has more volatility than hybrid variety. In case of HA, coarse and desi has more significant positive effect on the volatility of the growth of price than hybrid. The volatility is more in case of growth of price for superior quality bajra than hybrid for KA. The growth of price of bajra is more volatile in case of local and small than coarse for RA. In case of TN again local variety has more effect on the volatility of price of bajra. In case of UP, the volatility in the growth of price of bajra is less in case of dara than local and FAQ variety. In case of maize the volatility of the growth of price for yellow variety of maize is more than white variety maize for GU. In case of MP, white has more positive and significant effect on the volatility than yellow. Similarly, coarse variety maize has positive and significant effect on the volatility of the growth of price than local variety in case of PU. In RA, the growth of price is more volatile for local, red and coarse than yellow variety of maize. For gram, the volatility of the growth of price is more in case of desi variety for MP and PU. But in case of RA, FAQ variety has significant and positive effect on the volatility of the growth of price for gram. In case of BI, MA and UP, GARCH (2, 2), EGARCH (1, 1) and GARCH (1, 2) respectively are the best fitted model. Among the cash crops in case of cotton, growth of price of laxmi variety cotton is more than the other variety for AP and KA. In case of groundnut pods variety groundnut has more positive effect on the volatility of growth of price of groundnut for AP. On the other hand shell variety of groundnut is more volatile than bold in case of GU. For KA and TN there is only one variety and EGARCH (3, 3) and GARCH (1, 1) respectively are the best fitted model for these two states. For Rapeseed/Mustard Oil, the volatility of the growth of price of Rapeseed/Mustard Oil is more in case of lahi and laha variety than yellow variety for UP and rai variety for WB.

One important aspect of our study is that it can highlight which of the existing variety will give us more return.

In nutshell from the results of the GARCH estimation by considering different variety for different crops and states it is observed that the following variety gives more return:

- Rice: AP: Coarse and Hamsalu; KA: Fine and Coarse; OR: Fine and Coarse; PU: Fine and Basmati; WB: Coarse
- Wheat: BI: White; HA: Dara; UP: White and Imported
- Jowar: GU: Yellow; TN: Red; UP: White
- Bajra: AP: Local; HA: Coarse and Desi; KA: Superior; RA: Loacl and Small; TN: Local; UP: Local and FAQ
- Maize: GU: Yellow; MP: White; PU: Coarse; RA: Local, Red and Coarse
- Gram: MP: Desi; PU: Desi; RA: FAQ
- Cotton: AP: Laxmi; KA: Laxmi
- Groundnut: AP: Pods; GU: Shell
- Rapeseed/ Mustard Oil: UP: Lahi and Laha; WB: Yellow, Fresh and Desi

At the same time these variety affects the volatility of the growth of output price in positive way for each states and crops. So in summary, it can be concluded that under each crop different model of volatility is the best fitted model for different states. So volatility of growth of price varies from state to state under a certain crop also. This strong state-wise variation in the volatility in the growth of price is mainly due to the existence of different varieties because different varieties of crop have significant and positive effect on volatility for different states. The estimated mean equations for different states also support this fact because these varieties of crops have positive and significant effect on the return series of the growth of price for different selected crops.

Again for volatility analysis, an interesting observation is that in order to control the volatility in the output price a common policy for all crops and all states are not suitable because the nature of volatility varies from crop to crop and from state to state. Now, the variation in the volatility mainly comes from the different varieties of each crop for different states. So, in order to reduce the volatility in the output price Central or State Government have to control the output price of that specific variety which mainly leads to the volatility of that crop.

Results on Productivity

The results on the productivity issue discussed in chapter 5 can be summarized as follows:

First of all, the average annual rate of change of TFPG for **rice** suggests that overall average annual rate of change of TFPG in case of rice is 1.94% for the period 1970-71 to 2013-14. State-wise analysis of the results suggested that average annual rate of change of TFPG is negative only in case of AS (-0.48%) for the period 1970-71 to 2013-14. This rate of average annual rate of change of TFPG is highest in case of HA (3.67%) followed by PU (2.83%), OR (2.42%), BI (2.33%), KA (2.04%), MP (1.94%), WB (1.08%), UP (1.21%), TN (1.009%) and AP (0.75%). For decadal analysis the overall period 1970-71 to 2013-14 is broken down into four sub periods 1970-79, 1980-89, 1990-99 and 2000-2013. The decadal average annual rate of TFPG implies that this change is highest for the period 1970-79 (4.35%). The overall average annual rate of change of TFPG declined from 4.35% in 1970-79 to 2.87% in 1980-89 to 1.88% in 1990-99. In the period 2000-2013, the average annual rate of TFPG is negative (-1.96%). This may occur because nine among the eleven major rice producing states experience a negative average annual rate of TFP changes for the period 2000-2013. The overall decline in average annual rate of changes of TFPG may be visualized by its decline for 10 states out of 11 for the period 1970-79 to 1980-89 and 7 states out of 11 for the period 1980-89 to 1990-99 along with corresponding decline associated with the period 2000-2013. In case of wheat the results suggest that average annual rate of change of TFPG is 1.19% for the entire sample period but it this annual growth rate declined from 1970-79 (4.43%) to 1980-89 (1.7%) to 1990-99 (1.15%) as in case of rice. This annual growth rate is negative (-2.52%) for the period 2000-2013. During 1970-79 this average annual rate of change of TFPG is highest in case of PU (6.96%) followed by BI (6.31%), HA (5.3%), MP (4.54%), RA (2.43%) and UP (1.05%). During the period 1980-89 the average annual rate of change of TFPG is highest in case of MP (5.12%) followed by RA (4.2%), HA (2.55%), PU (1.69 %) and UP (1.5%). In case of BI, this growth rate is negative (-4.88%). During the period 1990-99 the average annual rate of change of TFPG is negative only in case of MP (-2.5%). This rate is highest in case of RA (4.26%). During the period 2000-2013, this annual growth rate is negative in case of five among the six major wheat producing states, only in case of BI this rate is positive (4.35%). In case of jowar the the average annual rate of change of TFPG is negative (-2.22%) for the period 2000-2013. During the period 1970 to 1979, the average annual rate of change of TFPG is highest in case of TN (7.03%) followed by MA (6.25%), AP (4.62%), RA (3.56%) and KA (0.12%). During the period 1980-89 this rate of growth is again highest in case of TN (7.77%) and lowest in case RA (2.01%). But during 1990-99, TN experienced a negative growth rate (-2.08%). During this period the rate of growth is highest in case of AP (3.8%). During 2000-2013, the average annual rate of change of TFPG is negative in case of AP (-5.24%), MA (2.93%) and TN (-5.38%).

Secondly, from the results of the decomposition analysis of TFPG it can be concluded that in case of **rice** productivity growth is mostly driven by the change in the scale efficiency for the entire sample period. The change in the technical efficiency is another major factor behind the increase in the productivity growth. The change in the technology has the lowest impact on the increase in the productivity. So it can be concluded that better utilization of factors of production and changes in the scale may push the states to be on higher TFPG in case of rice for the period 1970 to 2013. Now for this period AP, OR and WB experienced a technological regress and WB experienced a decline in the scale efficiency. In case of **wheat** productivity growth is mostly driven by the change in the scale efficiency for the entire sample period. The change in the technology has also an impact on the increase in the productivity. Because three states namely HA, PU and RA showed technological progress for the entire sample period. So it can be concluded that use of superior technology and changes in the scale may push the states to be on higher TFPG for the period 1970-71 to 2013-14. In case of HA and PU, the technological progress occurred only for the period 1970-79. But for the rest of the period HA and PU experienced either no technological progress or technological regress. In case of BI and RA apart from scale efficiency change productivity is also found to change due to improvement in the technological efficiency. So, for these states better utilization of factors of production may also push the states to be on higher TFPG. For **jowar** it can concluded that as in case of rice and wheat, productivity growth for jowar is also mostly driven by the change in the scale efficiency for the entire sample period. In case of AP and KA, apart from scale efficiency change productivity has also changed due to improvement in the technological efficiency and change in the technology. For AP and KA there is an improvement in the technical efficiency during the entire sample period. Not only this, these two states showed technological progress during this period. Thus for these two states better utilization of factors of production, superior technology and changes in the scale may push up the states to the higher TFPG level for jowar over the period 1970-71 to 2013-14.

Thus in conclusion it can be noted that scale changes are the most important factor causing in the productivity changes for all the three crops. Among the two other alternative sources of TFPG, efficiency changes dominates over technical changes in case of **rice** and the reverse is true for **wheat**. For **jowar** no such conclusive statement can be made regarding the dominance of technical changes over the efficiency changes or vice-versa. In case of rice, the improvement in the technical efficiency may push the states to a higher TFPG. In case of wheat the superior technology is another factor for the improvement in productivity.

There also exists a strong interstate variation behind the causes of the improvement in the productivity. During the same sub period some states experienced technological progress where as some other have technological regress. Also the decadal performance of a particular state varies regarding the relative movement of technological changes and efficiency changes. States experiencing technological progress in some decade has shown technological regress in the other decade. Same conclusion holds for technical efficiency also. Regarding scale efficiency change it can be inferred that most of the states have experienced an improvement in the scale for most of the decade.

Finally, the results of the major determinants as revealed by the estimation of simultaneous panel approach suggest that there exists two way dependence between TFPG and growth of HYV uses. Growth of HYV uses affect TFPG of different crops as well as get affected by movement of TFPG. However, the nature of the relationship between TFPG and growth of HYV uses varies among different crops. Also, the factors influencing TFPG other than HYV uses are different across different crops. Further, the relationship turned out to be nonlinear in explanatory variable, but the nature of the nonlinearity varies across different crop. Considering the factors influencing TFPG for example for **rice**, it can be concluded that the TFPG of rice is non-linearly and significantly related with rainfall, HYV uses, private irrigation and Agricultural loan. Although there exists non-linear relationship between these variables with the TFPG of rice but the marginal effect of these variables is positive implying that an increase in these variables will in turn encourage TFPG of rice. Among these variables there exists an inverted U shaped relationship between rainfall and TFPG for rice implying that too much rainfall is bad for TFPG. Again there exists an interaction term between HYV uses and private irrigation implying that the effect of the HYV uses on the TFPG is dependent on private irrigation and vice-a-versa. Also there exists another interaction term between private irrigation and agricultural loan and the implication is same as above. Apart from these variables, rural literacy and Government expenditure on Agricultural research and extension has a positive, linear and significant effect on the productivity of rice. There exists a U shape kind of relationship between inequality in the distribution of operational land holding and the productivity of rice but the marginal effect of inequality in the distribution of operational land holding is negative implying that an increase in inequality in distribution of operational land holding may adversely affect productivity. In case of **wheat,** the productivity of wheat is positively and significantly related with growth of rainfall and HYV uses. These relations are non-linear in nature (inverted U shaped) but as marginal effect of these variables is positive so an increase in these variables will stimulate TFPG of wheat. On the other hand, government irrigation, agricultural loan, rural literacy and Government expenditure on Agricultural research and extension has a positive and significant effect on the productivity of wheat but this relationship is not non-linear in nature. There exists a non-linear relationship between inequality in the distribution of operational land holding and the productivity of wheat but a negative marginal effect of inequality in the distribution of operational land holding implies that an increase in the inequality of distribution of land holding will decrease the TFPG of wheat. In case of jowar, the productivity of jowar is positively and significantly related with rainfall and HYV uses. These relations are non-linear in nature as in case of rice and wheat. On the other hand, government irrigation, Government expenditure on Agricultural research and extension and agricultural loan has a positive and significant effect on the productivity of jowar but this relationship is linear in nature. There also exists a non-linear relationship between inequality in the distribution of operational land holding and the productivity of jowar and the implication is similar to rice and wheat case.

Similarly, considering the factors influencing growth of HYV uses it can be said that in case of **rice** for growth of HYV use equation there exists an inverted U shape relationship between growth of HYV uses and productivity but the marginal effect of TFPG is positive implying that an increase in TFPG will stimulate growth of HYV uses. Apart from this, growth of HYV uses is positively, linearly and significantly related with private irrigation, Government expenditure on Agricultural research and extension, rural literacy and agricultural loan but these relations are linear in nature. Considering the factors explaining the variation in HYV uses in case of **wheat** it can be found that HYV uses is positive, linearly and significantly related with government irrigation, agricultural loan, Government expenditure on Agricultural research and extension and rural literacy. Growth of HYV uses of wheat is nonlinearly and significantly related with TFPG of wheat and the implication of this result is as similar as in case of rice. In case of **jowar** for growth of HYV uses equation it can be found that HYV uses is positive and significantly related with government irrigation, agricultural loan, Government expenditure on Agricultural research and extension and rural literacy. These relations are linear in nature. Similarly as in case of rice and wheat there exists a non-linear relationship between productivity of jowar and HYV uses.

Thus the result reveals that although the green revolution policies may push the TFPG in a higher level but the effect of green revolution policy may fade out over time. From the determinant analysis, it can be said that for each of the crop one can identify certain common policy that will boost up TFPG and the growth of HYV uses. These policies are of crucial importance because those have two way effects. By increasing the growth of HYV uses they

will in turn also boost up TFPG. For example, the common policy variable that will boost up TFPG and growth of HYV uses are (i) private irrigation, availability of agricultural loan, rural literacy, government expenditure on agricultural research and extension for rice, (ii) Government irrigation, availability of agricultural loan, rural literacy, government expenditure on agricultural research and extension for wheat and (iii) Government irrigation, availability of agricultural loan, rural literacy, government expenditure on agricultural research and extension for jowar. Thus in order to encourage total factor productivity growth, any policy changes that will lead to increase in the government and private irrigation, availability of agricultural loan, rural literacy, government expenditure on agricultural research and extension should be emphasized. Also heavy rainfall may hamper the total factor productivity growth. Although there exists non linear relationship (i) between TFPG and the growth of HYV uses, the marginal effect of HYV uses is positive implying that an increase in growth of HYV uses will push up TFPG and (ii) between TFPG and the inequality in operational land holding but the marginal effect of the inequality in the operational land holding is negative suggesting that an increase in inequality in operational land holding will reduce TFPG.

A Comparison of Growth, Volatility and Productivity

Comparison of Growth, extent of Volatility and Productivity are made in chapter 6 which suggests that

Since TFPG analysis is made on the basis of only three crops: Rice, Wheat and Jowar, to find out the relative position of major crops and states with respect to growth of output, volatility and total factor productivity growth, the 3 common crops i.e. rice, wheat and jowar, are taken into consideration in one group. On the other hand rests of 6 crops are taken into consideration in second group. For the second group only growth of output and volatility has been taken into consideration for comparison for determining the relative position of the crops.

So, first of all on the basis of crop-wise comparison the results suggests that the growth performances of all the crops are moderate but volatility is present in the growth of output price series of all the crops. The TFPG has increased in case of all three crops. Now by comparing the results of growth, volatility and productivity it can be concluded that the overall performances of all the crops are poor.

Secondly, state-wise analysis under a particular crop suggest that: In case of **Rice**: Good Performer: Nil; Moderate Performer: BI, HA and MP; Poor Performer: AP, AS, KA, OR, PU, TN, UP and WB; the criterion of classification explained in chapter 3 of this thesis. In case of Wheat: Good Performer: Nil; Moderate Performer: Nil; Poor Performer: BI, HA, MP, RA, PU and UP; In case of Jowar: Good Performer: Nil; Moderate Performer: AP and MA; Poor Performer: GU, KA, RA, UP and TN; In case of Bajra: Good Performer: Nil; Moderate Performer: GU; Poor Performer: AP, HA, KA, MA, RA, TN and UP; In case of Maize: Good Performer: Nil; Moderate Performer: AP, BI and KA; Poor Performer: GU, HP, MP, PU, RA and UP; In case of Gram: Good Performer: Nil; Moderate Performer: HA; Poor Performer: BI, MP, MA, PU, RA and UP; In case of Cotton: Good Performer: Nil; Moderate Performer: GU, HA, PU and RA; Poor Performer: AP, KA, MP and MA; In case of Groundnut: Good Performer: Nil; Moderate Performer: MP; Poor Performer: AP, GU, KA and TN; In case of Rapeseed/Mustard Oil: Good Performer: Nil; Moderate Performer: MP and RA; Poor Performer: AS, GU, HA, UP and WB

Thirdly, a state-wise analysis over the all crops suggests that: Good Performing States: Nil; Moderate Performing States: HA; Bad Performing States: AP, AS, BI, GU, HP, KA, MA, MP, OR, PU, RA, TN, UP and WB.

Fourthly, by considering the entire results it can be concluded that for each crop performance of most of the states is bad. That is for these states either performance of growth is bad or there exists volatility in the price series or the TFPG is low. Only for few states the performance is moderate. That is the growth performance is moderate and there exists no volatility in the price series and the TFPG is above average. If one considers the state-wise performance the picture is same. Only for one state out of fifteen the performance is moderate.

So the major problems in the Indian agricultural sector are that:

- **Moderate or bad performance with respect to growth of output**
- **Low total factor productivity growth**
- **There exists volatility in the price series for all the selected crops.**

Finally, a comparison of the factors that stimulates growth and TFPG reveals that either government irrigation or private irrigation, government expenditure on agricultural education, research, and extension, rural literacy and agricultural loan are common to both output growth and TFPG assigning some kind of a double role to these variables. Thus these variables are crucially important in enhancing growth and TFPG of the concerned crop of the relevant states.

Policy Suggestions

So, the analysis reveals that in order to foster growth and productivity of Indian Agricultural Sector, any policy changes that will lead to increase in availability of agricultural loan, area under government irrigation or private irrigation, government expenditure on agricultural education, research and extension and rural literacy should be emphasized. Likewise policy changes leading to decrease in the inequality in the distribution of operational land holding will help in promoting total factor productivity growth and growth of output. Lastly, in order to minimize the instability in the growth of price any policy changes leading to decrease in the volatility of the growth of output price will be taken immediately.

If one considers the simultaneity between growth of output and growth of HYV uses, then it can be found that both growth of output and growth of HYV uses are positively related to the growth of government irrigation, private irrigation, agricultural loan, government expenditure on agricultural research and extension and rural literacy rate implying that these variables are of crucial importance as increase in these variables can foster increase in output growth as well as growth in HYV uses. Increase in growth of HYV uses in turn will increase growth of output. Another policy variable which will have positive effect on both the growth of output as well as on the growth of HYV uses are the interaction term between the expenditure on agricultural research and extension and agricultural loan showing that the sensitivity of either the growth of output or growth of HYV uses with respect to the government expenditure on agricultural research and extension will depend on the availability of agricultural loan. Similarly, the sensitivity of either the growth of output or growth of HYV uses with respect to agricultural loan will in turn depend on the government expenditure of agricultural research and extension.

On the other hand if one considers the simultaneity between TFPG and growth of HYV uses, then it can be found that the variables that are common to both TFPG and growth of HYV uses are the growth of government irrigation, private irrigation, agricultural loan, government expenditure on agricultural research and extension and rural literacy rate implying that these variables are of great importance as increase in these variables can foster increase in TFPG as well as growth in HYV uses. Increase in growth of HYV uses will in turn stimulate TFPG.

Therefore the comparison of the variables that will stimulate the output growth, the growth of HYV uses and also the TFPG reveals that the growth of government irrigation, private irrigation, and agricultural loan, government expenditure on agricultural research and extension and rural literacy rate can increase all three variables: output growth, HYV uses and TFPG. Therefore, the government must promote its irrigation facilities, provide more agricultural loan and expenditure on agricultural research and extension and also take measures to increase rural literacy rate and also to stimulate private irrigation facilitates.

Limitations of the study

The limitation of the study is that due to unavailability of data, analysis related to extent of volatility in output for all the selected crops and states and for output prices of some sates under each crop is not possible. Further, the computation of TFPG, its decomposition and the factors influencing the movement of TFPG cannot be done for the crops namely Bajra, Maize, Gram, Cotton, Groundnut and Rapeseed / Mustard Oil due to unavailability of input data.

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Appendix I

Panel Analysis: Fixed and Random Effect Model

One of the main advantage of a panel data set over a cross section is that panel data set will allow the researcher great flexibility in modeling differences in behavior across individuals. The basic framework for this discussion is a regression model of the form

$$y_{it} = x'_{it}\beta + z'_i\alpha + \varepsilon_{it} \qquad \text{A.1.1}$$

$$= x'_{it}\beta + c_i + \varepsilon_i \qquad \text{A.1.2}$$

Let there are *K* regressors in x_{it}, not including a constant term. The heterogeneity, or individual effect is $z'_i\alpha$ where z_i contains a constant term and a set of individual or group specific variables, which may be observed and c_i is unobserved. The main objective of the analysis will be consistent and efficient estimation of the partial effects,

$$\beta = \partial E[y_{it} \mid x_{it}]/\partial x_{it} \qquad \text{A.1.3}$$

Now foe estimating the Panel regression analysis one can consider either

I) Fixed Effect Model

Or

II) Random Effect Model

Fixed Effects: If z_i is unobserved, but correlated with x_{it}, then the least squares estimator of β is biased and inconsistent as a consequence of an omitted variable. In case pf fixed effect model one can consider the following model

$$y_{it} = x'_{it}\beta + \alpha_i + \varepsilon_{it} \qquad \text{A.1.4}$$

Where $\alpha_i = z'_i\alpha$, captures all the observable effects and specifies an estimable conditional mean. In case of fixed effects model, α_i to be a group-specific constant term. It should be noted that the term “fixed” as used here signifies the correlation of c_i and x_{it} in equation A1.2, not that c_i is nonstochastic.

Random Effects: When unobserved individual heterogeneity, can be assumed to be uncorrelated with the included variables, then one can consider the following model

$$y_{it} = x'_{it}\beta + E[z'_{i}\alpha] + \{z'_{i}\alpha - E[z'_{i}\alpha]\} + \varepsilon_{it} \quad \text{A.1.5}$$

$$= x'_{it}\beta + \alpha + u_i + \varepsilon_{it} \quad \text{A.1.6}$$

That is, as a linear regression model with a compound disturbance that may be consistently, albeit inefficiently, estimated by least squares. This random effects approach specifies that u_i is a group-specific random element. The crucial distinction between fixed and random effects is that whether the unobserved individual effect represents elements that are correlated with the regressors in the model or not, not whether these effects are stochastic or not.

Hausman's test for the Random Effects Model

For estimating the model under Panel set-up one can consider two types of specification, i) Fixed Effect Model or ii) Random Effect Model. Now to test which specification is better one have to consider the Hausman's test which says that the random effects are independent of the right hand side variables. The test is based on the assumption that under the hypothesis of no correlation between the right hand side variables and the random effects are consistent estimators but fixed effects is inefficient.

The test is based on the following Wald statistic:

$$W = [\boldsymbol{\beta}_{FE} - \boldsymbol{\beta}_{\mathbf{RE}}]' \boldsymbol{\Psi}^{-1}[\boldsymbol{\beta}_{FE} - \boldsymbol{\beta}_{\mathbf{RE}}]$$

where $Var[\boldsymbol{\beta}_{FE} - \boldsymbol{\beta}_{\mathbf{RE}}] = Var[\boldsymbol{\beta}_{FE}] - Var[\boldsymbol{\beta}_{RE}] = \boldsymbol{\Psi}$

W is distributed as X^2 with (K-1) degrees of freedom where K is the number of parameters in the model. If W is greater than the critical value then we reject the null hypothesis of that both estimators are consistent i.e. of "no correlation between the right hand side variables and the 'random effects' and in this case the fixed effects model is better.

Appendix II

Abbreviation and Description of the variables Used in this Thesis:

- **GR: Growth of Output:** Growth of Output is the logarithmic value of Output.
- **PRO:** Total Factor Productivity Growth calculates on the basis of output and inputs.
- **HYV: Growth of HYV Uses:** It is measured by the percentage of the cultivated area using high yielding varieties of seeds in logarithmic form.
- **GI/ PI: Growth of Government / Private irrigation:** The variable GI representing share of Government irrigation in total irrigation and the variable PI measuring share of Private irrigation in total irrigation in logarithmic term.
- **RF: Growth of Rainfall:** The variable RF is the log value of amount of annual rainfall in the state in a given year.
- **E: Growth of Government expenditure on agricultural education, research, and extension:** Growth of Government expenditure on agricultural education, research and extension is the amount of expenditure divided by total area under agricultural operation in logarithmic value.
- **RL: Growth of Rural literacy:** Growth of Rural Literacy is the logarithmic value of Rural Literacy.
- **AL: Growth of Agricultural Loan:** Growth of Agricultural loan is the total amount of credit issued by rural banks and agricultural cooperatives per acre of cultivated area in the state in logarithmic form.
- **G: Growth of Inequality of Distribution of Operational Land Holding (G):** The inequality of distribution of operational land holding is measured by the logarithmic value of Gini ratio.

  Gini coefficient is defined as a ratio of the areas on the Lorenz Curve diagram. If the area between the line of perfect equality and Lorenz curve is A, and the area under the Lorenz curve is B, then the Gini coefficient is

  $$G = \frac{A}{(A+B)} \quad \text{A2.1}$$

  Since A+B=0.5, then the Gini coefficient (G) =2A=1-2B.

If the Lorenz curve is represented by the function $y = L(x)$, the value of B can be found will integration and:

$$G = 1 - 2\int_0^1 L(x)dx \qquad A2.2$$

Sometimes, the entire Lorenz curve is not known, and only values at certain intervals are given. In that case, Gini coefficient can be approximated by using various techniques for interpolating missing values of the Lorenz curve. If (X_k, Y_k) are the known points on the Lorenz curve, with the indexed with increasing order $(X_{k-1} < X_k)$ so that :

- ✓ X_k is the cumulated proportion of the population variables, for k=0, …., n with $X_0 = 0$ and $X_n = 1.0$
- ✓ Y_k is the cumulated proportion of the income variables, for k=0, …., n with $Y_0 = 0$ and $Y_n = 1.0$

If the Lorenz curve is approximated on each interval as a line between consecutive points, then the area B can be approximated with trapezoids and

$$GINI = 1 - \sum_{k=1}^{n}(X_k - X_{k-1})(Y_k + Y_{k-1}) \qquad A2.3$$

is the resulting approximation for G.

In our present problem, we intend to construct the Gini coefficient for agricultural landholdings. We have the data on numbers of farmers and the area of land holding for the following intervals i.e., for the following groups of farmers- marginal (below 1 hectares), small (1-2 hectares), semi-medium (2-4 hectares), medium (4-10 hectares) and large.

We will take number of farmers for each interval as X value and the area of holding a Y value and calculate the Gini coefficient using the relation A2.3.

DN is the dummy variable for Northern Region, **DW** is the dummy variable for Western Region, **DS** is the dummy variable for Southern Region, **DM** is the dummy variable for Middle Region and **DE** is the dummy variable for Eastern Region.

Appendix III

Major Selected Crops and Major Producing States

Food crops: Rice, Wheat, Maize, Jowar, Gram, Bajra.

- ✓ Rice- Andhra Pradesh (AP), Assam (AS), Bihar (BI), Haryana (HA), Karnataka (KA), Madhya Pradesh (MP), Orissa (OR), Punjab (PU), Tamil Nadu (TN), Uttar Pradesh (UP), West Bengal (WB).
- ✓ Wheat- Bihar (BI), Haryana (HA), Madhya Pradesh (MP), Rajasthan (RA), Punjab (PU), Uttar Pradesh (UP).
- ✓ Maize(Corn)- Andhra Pradesh (AP), Bihar (BI), Gujarat (GU), Himachal Pradesh (HP), Karnataka (KA), Madhya Pradesh (MP), Punjab (PU), Uttar Pradesh (UP), Rajasthan (RA).
- ✓ Jowar(Sorghum)- Andhra Pradesh (AP), Gujarat (GU), Karnataka (KA), Maharashtra (MA), Rajasthan (RA), Tamil Nadu (TN), Uttar Pradesh (UP).
- ✓ Gram- Bihar (BI), Haryana (HA), Madhya Prades (MP), Maharashtra (MA), Rajasthan (RA), Uttar Pradesh (UP).
- ✓ Bajra(Peari Millets)- Gujarat (GU), Haryana (HA), Karnataka (KA), Maharashtra (MA), Rajasthan (RA), Uttar Pradesh (UP).

Cash crops or Non Food crops: Cotton, Groundnuts, Rapeseed/Mustard Oil.

- ✓ Cotton- Andhra Pradesh (AP), Gujarat (GU), Haryana (HA), Karnataka (KA), Madhya Pradesh (MP), Maharashtra (MA), Punjab (PU), Rajasthan (RA).
- ✓ Groundnuts- Andhra Pradesh (AP), Gujarat (GU), Karnataka (KA), Madhya Pradesh (MP), Tamil Nadu (TN).
- ✓ Rapeseed/Mustard- Assam (AS), Gujarat (GU), Haryana (HA), Madhya Pradesh (MP), Rajasthan (RA), Uttar Pradesh (UP), West Bengal (WB).