Policy Paper 25

# Total Factor Productivity and Contribution of Research Investment to Agricultural Growth in India

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ICAR

राष्ट्रीय कृषि आर्थिकी एवम् नीति अनुसंधान केन्द्र
NATIONAL CENTRE FOR AGRICULTURAL ECONOMICS AND POLICY RESEARCH

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# Foreword

Deceleration in agriculture growth after mid-1990s has raised several concerns. India's population is still rising at about 1.4 per cent per annum resulting in net addition of 1.6 crore persons each year. This implies that even to maintain current level of per capita availability of agri-food products India requires a minimum 1.4 per cent growth in agri-food output. However, this is gross underestimation of the total demand for agri-food products in the country. As the present level of per capita consumption of most of the food items is much below the minimum requirement of a healthy diet, there is a need to raise per capita consumption to reduce undernutrition and hunger in the country. Further, dietary pattern is changing towards costly energy food and protein rich food which implies more output to derive given level of nutrition. All these factors necessitate that agri-food production in India must move on high growth trajectory to meet future demand and requirement.

While demand for agriculture and food products is rising at a high rate, the resource base for production is shrinking. This implies that more output needs to be produced per unit of bundle of resources. This requires a paradigm shift from increase in productivity from a single resource (partial productivity) to productivity of entire set of resources used in production i.e. Total Factor Productivity (TFP). And, this has to achieved in a production environment facing rising and new stresses. This poses a serious challenge. Contribution of technology is crucial to face this challenge and to achieve desired growth in agri-food production. This policy paper undertakes in depth analysis of contribution of technology and other such factors which contribute to growth in TFP. As it is obvious, generation and dissemination of technology depends upon investments made in agricultural research and education and agricultural extension. The paper quantifies role of TFP in output growth and role of R&E and extension and other factors in growth of TFP of selected crops at country level and in major states during various periods since mid-1970s.

The findings of the study would be useful in understanding growth and to plan strategy for future growth of crop output at state level. The paper makes a strong case for raising public funding for agricultural research and extension by demonstrating return to investments in research and education and contribution of research to food self-sufficiency.

Besides research content, the paper develops series of information on resources allocated for agriculture research and education and extension in the country since 1960. This series would be useful to other researchers and all those who have interest in public investment in agriculture R&D.

**Ramesh Chand**
Director

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**Authors**

# Acronyms and Abbreviations

| | |
|---|---|
| AgGDP | Agricultural Gross Domestic Product |
| DES | Directorate of Economics and Statistics |
| EVMP | Estimated Value of Marginal Product |
| GDP | Gross Domestic Product |
| GoI | Government of India |
| IRR | Internal Rate of Return |
| NARI | Natural Agricultural Resources Index |
| R&M | Rapeseed and Mustard |
| RCP | Real Cost of Production |
| TFP | Total Factor Productivity |
| TFPG | Total Factor Productivity Growth |
| TII | Total Input Index |
| TOI | Total Output Index |
| V-PAGe | Visioning, Policy Analysis and Gender |

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# Executive Summary

The initial phase of green revolution (mid-1970s to mid-1980s) in India was marked by growth in agricultural productivity of cereal crops in some parts of the country through adoption of high-yielding varieties, increased use of inputs like fertilizers, agricultural chemicals, improved seeds, machine labour and expansion in area under irrigation. The second phase of green revolution, beginning around mid-1980s, involved a wider dissemination of technology and higher inputs-use, though somewhat indiscriminate across regions and crops. With the spread of green revolution technology, many inimical trends and ecological problems have cropped-up in agriculture in various parts of the country. They include nutrient imbalance and nutrient mining in soils, over-exploitation of groundwater resources, land degradation and outbreaks of agricultural pests and diseases. These negative externalities of high input-intensive agriculture pose a serious challenge to maintaining of growth in productivity, sustainable use of natural resources for crop production, economic viability, farm income, and national food security.

In recent years, crop sector has been experiencing diminishing returns to input-use and some areas are facing stagnation or negative growth in productivity of some crops. This calls for an in-depth examination of the issues related to the growth in agricultural productivity, which can be better understood by looking at the trends in 'Total Factor Productivity' (TFP) and by separating out the effect of inputs and other factors like technology, infrastructure, and farmers' knowledge on productivity growth. This study is an attempt in this direction. It has also analysed the role of agricultural research in output growth and has estimated the contribution of agricultural research to India's economy and attainment of food self-sufficiency in the country.

The study has used farm-level data collected under the "Comprehensive Scheme for the Study on Cost of Cultivation of Principal Crops", Directorate of Economics and Statistics (DES), Ministry of Agriculture, Government of India (GoI), to compute TFP indices. The time series data on infrastructural variables (road and rail density, consumption of electricity in agriculture), cropping intensity, fertilizers, source-wise irrigated area, land-use pattern and literacy have been collected for different states of India from various publications of GoI and for respective states. Besides, public investments on agricultural research including education and on extension expenditures data series from 1960s to 2007-08 have been compiled from various official documents of the central and state governments, and have been reported in the study for the benefit of other researchers and users. These data include all expenditures on agricultural research including education and on extension under Plan and Non-plan Heads on Revenue as well as Capital accounts.

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.

More than half of the total growth in output of wheat and around one-fourth in other cereals have been contributed by the increase in TFP. Out of 18 crops selected for the study, two-thirds have exhibited a decline in TFP after mid-1990s.

The TFP growths have indicated that technological gains have not been experienced in a number of crops in many states. Some states have even shown a negative, stagnant or poor growth in TFP for some of the crops under the study. Only a few states have depicted outstanding performance of productivity growth and technological change which has moved the average productivity gain at the country level to a comfortable position, leading to the impression that technological gains have taken place in almost all the crops at the country level. However, the disaggregate analysis has shown that a number of states and crops have not experienced benefits of technological progress. The priority must be focussed on those states for which TFP has shown a declining trend in growth. If the sustainability issue of crop system, as implied by TFP trend, is not addressed properly, it will adversely affect the long-term growth as well as the national food security and household nutritional security.

The states of Punjab, Gujarat, and Andhra Pradesh have been found to fall under high TFP growth status with almost 90% or more cropped area experiencing a moderate to high growth in TFP (more than 1%). About 60 per cent area in Rajsthan has witnessed more than 1% growth in TFP. Tamil Nadu, Haryana, Uttar Pradesh, and Maharashtra states have experienced low to high TFP growth, the cropped area being distributed across all TFP growth classes. The other states, viz. Madhya Pradesh, West Bengal, Bihar, Orissa, Kerala, Karnataka, and Himachal

Pradesh have shown a relatively low performance in productivity growth and a large share of their cropped area falls under negative, stagnant or poor productivity category.

The TFP growth score has revealed that technology-driven growth has been highest in Punjab and lowest in Himachal Pradesh. The TFP growth score of crop sector in Gujarat, Andhra Pradesh, Rajasthan, and Tamil Nadu is higher than the all-India index, whereas for the states of Uttar Pradesh, Maharashtra, Assam, Madhya Pradesh, West Bengal, Bihar, Orissa, Kerala, Karnataka and Himachal Pradesh, this score is below the average value of the country. Based on this observation it can be concluded that the states of Madhya Pradesh, West Bengal, Bihar, Orissa, Kerala, Karnataka and Himachal Pradesh must receive a higher priority in the research resource allocations, infrastructural development and technology generation and dissemination to improve sustainability of the growth process in agriculture.

Research and technology led output growth has helped in reducing the real cost of production in the range of 1.0-2.3% per annum during the past three decades in the case of cereals. The largest decline in the real cost per unit of output has been witnessed in wheat. This has helped in keeping the cereal prices low for consumers while benefiting producers through a decline in the real cost of production.

The public policies such as investments in research, extension, education and infrastructure, and natural resource management have been the major sources of TFP growth. The TFP is influenced by research, extension, human capital, intensity of cultivation, balanced application of plant nutrients, infrastructural development and climatic factors. The public investment in research has constituted a significant source of TFP growth in all the crops, except moong, urad, sugarcane and jute. Public investment in the transfer of technology (extension) has contributed positively towards TFP enhancement in pulses and sugarcane. The variables for natural agricultural resource management (NARM) and infrastructure have been important sources of TFP growth for most of the crops. Among natural resources, a reliable supply of irrigation revealed by the share of groundwater in total irrigation along with balanced use of fertilisers have played a significant role in enhancing TFP. Road density and electricity supply have been the most significant determinants of TFP.

Allocation of additional resources needs a higher priority for research, road network, groundwater irrigation for crops and for regions where the current yields are below the national average and the TFP growth is stagnating or decelerating, as identified in the study. Public investment in extension has not turned up an important source of TFP growth for a number of crops due to suboptimal investment below the critical level, as the ratio of amount spent on extension to that on research has been falling. Since a vast untapped yield potential exists in the country, much more intensive efforts are required to promote the processes of development as well as spread of the second-generation technologies in the country. Extension services need to be strengthened by scaling-up investment levels and by improving their quality. Road density would induce input-output market interface and would create a suitable environment for the adoption of technology, and induction of investments in agriculture.

The estimates derived from TFP elasticity with respect to research stock have shown that to achieve 1% increase in TFP, the investments in research need to be increased by 21.5% for rice, 19.5% for wheat, 19.3% for bajra, 13.6% for maize, and 8.7% for jowar. Across pulses, research investments will have to be increased by 5.2% for arhar and 10.7% for gram per annum. For edible oilseeds, research investment should be enhanced by 21.4% for rapeseed & mustard and 54% for groundnut to achieve 1% growth in TFP. For cotton, investment has to be raised by 12.7% per annum to maintain 1% TFP growth. On an average, the investments on research in agriculture need to be raised at the rate of about 25% per annum to increase 1% TFP.

To attain 4% agricultural growth, as targetted by the Planning Commission, at least one-third of this growth must come through technological innovations and the remaining two-thirds has to be achieved through additional use of agricultural inputs. To meet these targets, investments on agricultural research in real terms need to be doubled by 2015 and tripled by 2020 in relation to the investment level of 2002.

Returns to investment on research have been found to be a highly paying proposition. The overall internal rates of return to public investment in agricultural research during the period 1975 to 2005 turned out to be 29% for rice, 38% for wheat , 28% for maize, 39% for jowar, 31% for bajra, 34% for gram, 57% for arhar, 18% for groundnut, 20% for rapeseed & mustard, and 39% for cotton. The study has suggested that further investments on research will generate significant returns.

At the sectoral level (including crop and livestock), the TFP growth has contributed 15% to the total growth in output during 1990-91 to 2006-07, with annual growth of 0.42% in TFP, which is strongly affected by investments in agricultural research — 1% increase in investment on research in agriculture has led to 0.3% increase in TFP. The internal rate of return to investments in agricultural research has been estimated quite high (42%).

The share of TFP growth in output growth has been found to vary widely, ranging from 10.1% for rapeseed & mustard to 58.9% for wheat. The share of research in TFP growth has been estimated as 55.7% for rice, 40.1% for wheat, 79.2% for maize, 27.8% for jowar, 74.8 % for bajra, 42.2% for gram, 36.0% for groundnut, 88.6% for rapeseed & mustard and 26.4% for cotton. Based on these estimates, it has been found that around one-fourth growth in the output of wheat and cotton, one-fifth in the case of bajra, and around 13% in paddy and maize have been due to investments in agricultural research. In most of the other crops, about one-tenth of output growth has been due to public sector research, the lowest being 6.6% in the case of jowar. These estimates have been used to provide an idea about the contribution of agricultural research to incremental output in a given year. During 1975-76 to 2005-06, annual output of paddy has increased by 2.32%, of which 0.32 percentage point growth has been due to agricultural research; in terms of quantity, it comes out to be 0.4228 million tonnes (Mt). Valued even at the minimum support price, this incremental output is worth Rs 241 crore. Similarly, the contribution of research to wheat crop during 2005-06 has been estimated as 0.5896 Mt, valued at Rs 636.8 crore. Cotton crop ranks second after wheat in terms of contribution of research, which is valued at Rs 562 crore. The contribution of research to TFP growth for the whole crop sector has been found as Rs 3748 crore for the year 2005-06. This contribution is 33% more than the annual public investment on research in agriculture in the country. It is also pertinent to mention that the estimated contribution does not include role of research in improving quality of products which fetches premium price.

An important contribution of output growth achieved through agricultural research is the reduction in import dependency in meeting the food requirement of the country and improving the food self-sufficiency of the nation. It has been estimated that without the contribution of research, wheat production in the country in the year 2005-06 would have been lower by 10.4 Mt and rice production would have been lower by 6.3 Mt. The contribution of research in enhanced production of maize and bajra has been estimated as 1.09 Mt and 0.64 Mt, respectively. Cumulative effect of agricultural research on output of gram has been estimated as 80 thousand tonnes. In oilseeds, groundnut production would have been lower by 80 thousand tonnes and rapeseed & mustard production would have been turned 5.2 lakh tonnes lower without the contribution of research. During the year 2005-06, domestic demand for all the commodities, was much higher than what would have been the production in the country without contribution of research and India would have been far away from attainment of self-sufficiency status. Without the contribution of research, self-sufficiency in wheat would have declined to 83.4%. This implies that India would have been forced to import 9.8 Mt of wheat in the absence of research contribution. Similarly, without research contribution, India would have been forced to import 1.77 Mt of rice, after wiping out export of 4 Mt rice. Contribution of research in attainment of self-sufficiency in gram and groundnut has been limited. In the case of rapeseed

& mustard, import dependency of India would have increased from 34% to 38% without the contribution of research to output growth of rapeseed & mustard.

The agricultural research carried out during the past three decades has improved the self-sufficiency status in wheat by 15% and in rice by 7%. Growth in food production induced by research in India has reduced the import dependency of the country and has added to export, which amounted to 17 Mt of cereals — in value terms this comes to more than four-times the annual investment in agricultural research . It has also reduced pressure on the globally-traded food commodities. In the absence of contribution of research in India, the global supply of rice and wheat (quantity available for export) would have reduced by about 12%. This could result in a sharp increase in global grain prices causing adverse effect on food security of a large number of low-income food-deficit countries, including India.

In order to sustain food security and achieve the projected rise in production of food and non-food commodities, essentially through enhancing yield per unit of land, India needs to maintain a steady growth rate in TFP. As TFP increases, the cost of production decreases and consequently prices will fall and stabilize at a lower level. Therefore, both producers and consumers will be benefited.

A wide variation exists in allocation of resources across different years, ranging from 1% to 15%. Such large fluctuations in research allocation are not conducive to maintain a consistent research output in the agricultural sector. There is a need to maintain a smooth growth in allocation of research resources.

Since 2002-03, the government spending on research in agriculture has stagnated at around 0.6% of agricultural GDP. The share of agricultural GDP spent on agricultural extension has not shown any specific trend. In recent years, the government has spent about 0.14% of agricultural GDP on extension services. Contribution of agricultural research to attainment of food self-sufficiency and growth in TFP as well as high payoff to investment in agricultural research and extension are strong justifications for adequate funding for research and extension in agriculture. As recommended by some high level committees, the public funding for research and development (R&D) in agriculture should be raised to 1% of agricultural GDP towards the end of XI Plan. This requires a big increase in the allocation of public resources to agricultural research system of the country.

1

# Introduction

## Background

India has made considerable progress in agriculture by increasing production of cereals and other crops such as oilseeds, sugarcane, cotton, and fruits & vegetables during the past four decades. This success has been driven by several factors which include policy support, research and extension, production strategies, higher use of inputs, and public investment in infrastructure. It has helped the country to address many contemporary and future challenges of food security of its vast population.

In the first two Five-Year Plans after independence, India made massive investments in medium and major irrigation projects and implemented several institutional reforms. However, these measures could not help in raising food production to sufficiently high levels to meet the domestic demand and reduce dependence on imports of foodgrains. Rather, import dependency for food reached all-time high level during 1965 to 1967 when India had to import more than 26 million tonnes (Mt) of foodgrains in three years. The situation started changing during late-1960s with the adoption of new high-yielding varieties of cereals. Since then, India has not only reduced dependence on import, it has become self-sufficient in staple food production. It is important to mention that growth in production of several crops has outpaced the growth in demand, despite the fact that India's population has more than doubled during the past four decades (from 551 million in 1971 to 1186 million in 2010). This has resulted in increase in net export of food from India. Even the share of trade surplus (export minus import) in total food production has moved on a rising curve for the past many years.

Though almost all crops except some pulses and cash crops, have witnessed a significant growth in production as well as in productivity, the growth has been uneven across crops, regions and time periods. It is widely believed that cultivation of rice and wheat and areas endowed with irrigation have been the main beneficiaries of public policies and technology evolution. However, a sound empirical evidence that provides state-wise and crop-wise estimates of productivity growth achieved through various means is missing. Similarly, there is a serious concern about the recent trends in crop productivity which is echoed in the debates on technology fatigue and policy fatigue (Planning Commission, 2010; Narayanamoorthy, 2007). It is felt that the potential of green revolution technology has reached its limits and it is not capable to sustain the future growth in Indian agriculture. The debate is stretched to question the efficacy and contribution of research to the agricultural growth process. Again, sound empirical analysis of the sources of growth and contribution of factors like research, education, extension, infrastructure, natural resource management, etc. in raising the crop productivity and production in recent years is missing. This necessitates that growth in the productivity and its sources be examined by dividing the long post-green revolution period into shorter periods — the ones that capture recent trends.

The initial phase of green revolution (mid-1970s to mid-1980s) was marked by the growth in productivity through adoption of high-yielding varieties, sharp increase in the use of inputs like fertilizers, agricultural chemicals, improved seeds, machine labour and expansion in area under irrigation. The second post-green revolution phase, beginning around mid-1980s, was characterized by the spread of green revolution technology beyond the traditional green revolution belt of the first phase (Chand, 2008 p. 135). This phase involved higher inputs-use, though somewhat indiscriminate across regions and crops. With the spread of green revolution technology, many inimical trends and ecological problems have cropped-up in various parts of the country. These include nutrient imbalance and nutrient mining in soils, over-exploitation of groundwater resources, land degradation and outbreaks of agricultural pests and diseases. These negative externalities of high input-intensive agriculture pose a serious challenge to maintaining of growth in productivity, sustainable use of natural resources for crop production, economic viability, farm income, and national food security. It calls for an in-depth examination of the issues related to the growth in agricultural productivity, which can be better understood by looking at the performance of individual crops in different regions in recent years.

The ‘Total Factor Productivity’ (TFP) approach is considered an appropriate tool to examine and understand the growth in agricultural productivity and to separate out the effect of inputs and other factors like technology, infrastructure, and farmers’ knowledge on productivity growth. Quite a few studies on agricultural productivity have been undertaken in India during the past four decades or so, using TFP approach. They focus on estimating the effect of technological change on agriculture as a whole or total crop sector (Evenson and Jha, 1973; Rosegrant and Evenson, 1992). Due to non-availability of input allocation data at individual crop level, this may over- or under-estimate the TFP for the crop sector to the extent that rates of technological change differ across crops. Some studies (Sidhu and Byerlee, 1992; Kumar and Mruthyunjaya, 1992; Kumar and

Rosegrant, 1994; Kumar, 2001) that have sought to estimate the TFP for individual crops, mainly rice and wheat, did not go beyond mid-1990s. No study on TFP is available at the aggregate or individual crop level that extends to recent years. The present study fills this gap by estimating the TFP of individual crops and agricultural sector as a whole, covering the recent period for which the required data was available. It also estimates the growth in TFP of agricultural sector as a whole in different periods. The study analyses the role of public sector agricultural research in output growth and estimates the contribution of agricultural research to India's economy and attainment of food self-sufficiency. Besides, data series on investment and stock of public sector research, education and extension from 1960s to 2007-08 are also reported in the policy paper for the benefit of other researchers and users.

## Objectives

The study has been conducted with the following objectives:

- To estimate the spatial and temporal changes in total factor productivity of major crops,
- To analyze factors affecting TFP of the selected crops,
- To identify the states and crops that need priority in research resource allocations,
- To measure the returns to investment on agricultural research,
- To assess the contribution of agricultural research to national food self-sufficiency, and
- To suggest policy measures to sustain and improve productivity growth in the key agricultural crops.

2

# Data and Methodology

## The Data

Farm-level data on yield, use of inputs and their prices for the period 1971-72 to 2005-06 were taken from the "Comprehensive Scheme for the Study of Cost of Cultivation of Principal Crops", Directorate of Economics and Statistics (DES), Ministry of Agriculture, Government of India (GoI), for the major crops grown in different states (Appendix 1). Based on farm-level data, statewise average data on cost of cultivation and yield that appeared in the Reports of the Commission for Agricultural Costs and Prices, published by the Department of Agricultural and Cooperation, Ministry of Agriculture, Government of India for principal crops were used for the study. The missing year data on inputs and their prices were predicted using interpolations based on trends in the available data. This data set provided a rich source for measuring and analyzing the agricultural productivity. Output series was constructed by multiplying the yield level of sample farm households included in the "Cost of Cultivation Scheme" data, with area under the respective crops in a state. The time series data on infrastructural variables (road and rail density, consumption of electricity in agriculture), cropping intensity, fertilizers, source-wise irrigated area, land-use pattern and literacy were collected for different states of India from various publications of GoI and respective states.

Historically, agricultural research, education and extension in India have largely been in the public domain. India has one of the largest and institutionally matured agricultural research systems in the world. The construction of a time series on agricultural research and extension expenditures has been a challenging task, because many of the data sources were inadequate in scope and coverage, difficult to access, without uniformity in quality, and varied in the degree of documentation. Pal and Singh (1997) have compiled government investment/expenditure in agricultural research and extension from various official documents of the Union and State governments (Comptroller & Auditor General of India, Ministry of Finance, and Reserve Bank of India). These data include all expenditures on agricultural research including education and on extension under Plan and Non Plan Heads on Revenue as well as Capital accounts. These data were updated from 1995 onwards up to the year 2007 (2007-08). Data series on government expenditure (both central and states) in agricultural research by sub-sectors and in agriculture extension compiled from the published sources (*Combined Finance and Revenue Accounts* *of the Union and State Governments*, CAG, various issues) since mid-1960s are presented in Appendices 2.1 to 2.4.

## Methodology

Voluminous literature has been published on measurement and analysis of agricultural productivity. Solow (1957) was the first to propose a growth accounting framework, which attributes the growth in TFP to that part of growth in output, which cannot be explained by growth in factor inputs like land, labour and capital. The other approaches used for measurement of productivity are the parametric approach and non-parametric approach. Among these, the 'accounting approach' is popular because it is easy to implement, requiring no econometric estimation. This approach gained prominence since Diewert (1976; 1978) proved that the Theil-Tornqvist discrete approximation to the Divisia index is consistent in aggregation and superlative for a linear homogeneous trans-logarithmic production function. Thus, Divisia Tornqvist index has been used in the present study for computing TFP for major crops listed in Appendix 1.

## Measurement of TFP

It has long been recognized that partial productivity measures, such as output per unit of individual input, are of limited use as indicators of real productivity change for two reasons. One, as productivity depends upon a large number of inputs and factors, the ratio of output to single input includes the effect of several inputs and factors. While the increased use of inputs, to a certain extent, helps the agricultural sector to move up along the production surface, a change in partial productivity cannot be attributed to a particular input. Two, shift in technology frontiers or production function is an important factor for increase in output. This may or may not be embodied in inputs use. This change is generally not solely attributable to input(s) but it gets included in the calculation of partial productivity. In some cases, the use of certain inputs may also induce an upward shift in the production function to the extent that a technological change is embodied in it. However, output per unit of input, or estimates of partial productivity are of limited use as indicators of real productivity change, as defined by a shift in the production function.

The TFP concept, which is based on an index of output per unit of total factor inputs, measures the increase in output due to various technological and knowledge-based factors other than inputs like land, labour, machinery, fertilizer, seed, etc. In other words, TFP corresponds to the change in productivity when all the inputs are held constant. Thus, TFP captures the amount of increase in total output that is not accounted for by increases in total inputs, but that occurs due to shift in production function, which could be due to improved technology, management, knowledge, infrastructure, and other knowledge-based factors.

The Divisia Tornqvist index has been used in this study for computing the total output, total input, and TFP indices for different states of India for major crops, which included cereals, pulses, edible oilseeds, sugarcane, cotton, jute, onion, and potato, using the farm-level data. The output index includes the main products as well as by-products. Farm harvest prices have been used to aggregate the output. The input index includes seed, manure, fertilizer, pesticide/herbicide, human labour, animal labour, machine labour, irrigation and land (rental value of land). Inputs have been aggregated using their farm rental prices.

The total output, total input and TFP indices have been calculated as under:

**Total output index (TOI)**

$$TOI_t / TOI_{t-1} = \prod_j (Q_{jt} / Q_{jt-1})^{(R_{jt}+R_{jt-1})^{1/2}} = A_t \quad \ldots(1)$$

**Total input index (TII)**

$$TII_t / TII_{t-1} = \prod_i (X_{it} / X_{it-1})^{(S_{it}+S_{it-1})^{1/2}} = B_t \quad \ldots(2)$$

where,

$R_{jt}$ is the share of $j^{th}$ crop output in total revenue in year t,

$Q_{jt}$ is the output of $j^{th}$ crop in year t,

$S_{it}$ is the share of input i in the total input cost in year t, and

$X_{it}$ is the quantity of input i in year t.

In the case of TFP for a single crop, revenue share refers to the share of main product and by-product in total revenue from the crop, while output includes main product and by-product.

Total output index (TOI) and total input index (TII) for the year t were computed from Equations (1) and (2) as follows:

$$TOI\ (t) = A_1\ A_2 \ldots\ldots\ldots\ldots A_t \quad \ldots(3)$$

$$TII\ (t) = B_1\ B_2 \ldots\ldots\ldots\ldots B_t \quad \ldots(4)$$

This way, streams of total output index (TOI) and total input index (TII) for different years (t) were computed from Equations (1) and (2), respectively.

The total factor productivity (TFP) index was computed from TOI and TII as under:

$$TFP_t = \{TOI\ (t)\ /\ TII\ (t)\} \qquad \ldots(5)$$

Equations (3) to (5) provide the index of total output, total input, and TFP, respectively for any given year ‘t’. The indices have been computed with the base year as 2005-06 =100. The real cost of production of crops was computed by deflating the cost of production by input price index. The estimation of input, output, and TFP growth rates for any specified period was done by fitting an exponential (or semi-log) trend equation to the five-yearly moving average input, output, and TFP indices, respectively. The study has estimated the changes in TFP across states in India which were then aggregated to get the country-level estimates of TFP for the major cereals, pulses, oilseeds, and other cash crops. This perspective is valuable because the states are the units for agricultural development and policy action in India.

Though TFP has been widely used as a measure to evaluate the performance of any production system and sustainability of the underlying growth process, some aspects of production and growth are not adequately captured by the TFP analysis. For instance, agricultural research has contributed to the breaking of seasonality in crop production. Similarly, a great deal of stability has been introduced in crop production by providing farmers with varieties that tolerate or resist adverse environmental conditions. Finally, quality improvements have added value to the production of agricultural commodities, as in the case of *Basmati* rice, but growth is seen in terms of quantity of output. Such contributions are generally not captured under a residual TFP measure. It would be worthwhile to explicitly identify these influences, which would lead to a more realistic assessment of the productivity of investment in agricultural research. Such aspects were beyond the scope of the present study because of non–availability of time series data on quality and related aspects.

## Sources of TFP Growth

The TFP can be affected by factors such as research, extension, human capital, intensity of cultivation, balanced application of plant nutrients, infrastructural development and climatic factors. As an input to public investment decisions, it is useful to understand the relative importance of these productivity-enhancing factors in determining productivity growth. In order to assess the determinants of TFP, the TFP index was regressed against the following variables:

RES_STOK (research stock per ha of crop area);

EXT_STOK (extension stock per ha);

LIT_R (the proportion of rural population which is literate);

NPRATIO (ratio of N to $P_2O_5$ nutrients used);

CI (cropping intensity, %);

IRR_GW (groundwater irrigated area to total irrigated area);

ROAD (road density, km per 100 sq km);

RAIL (rail density, km per 100 sq km);

ELECT_AG (electricity consumption per ha of crop area); and

DUMMY (state dummy).

Regression analysis was attempted using the above variables and by clubbing together variables related to natural resources and infrastructure. Three variables representing natural agricultural resources were clubbed together by taking their average as:

1/3 CI +1/3 NPRATIO + 1/3 IRR_GW.

Similarly, infrastructural index (INF) was computed from infrastructural variables as:

0.6 ROAD + 0.1 RAIL+ 0.3 ELECT_AG)
[the weights 0.6, 0.3 and 0.1 were based on the experts judgement].

Model 1 below uses NARI and INF indices to estimate the effect of various factors on TFP. All major individual variables representing natural resources and infrastructure were incorporated in model 2. Accordingly, the specification of regression equations was stated as:

Model 1: TFP = f (RES_STOK, EXT_STOK, LIT_R, NARI, INF, DUMMY)

Model 2: TFP = g (RES_STOK, EXT_STOK, LIT_R, CI, NPRATIO, IRR_GW, ROAD, ELECT_AG, DUMMY)

Estimation was undertaken using a fixed effect approach for the pooled cross-section time series state-level data set, with corrections for serial correlation and heteroskedasticity (Kmenta, 1981). Following Evenson *et al.* (1999), the research stock variable was constructed by summing up research investment of five years by assigning weights as 0.2 in the year t–2, 0.4 in the year t–3, 0.6 in the year t–4, 0.8 in the year t–5 and 1.0 in the year t–6. The extension stock variable was constructed by summing up three years' extension investment by assigning weights as 1.0 in the year t–1, 0.8 in the year t–2, and 0.4 in the year t–3.

## Returns to Research Investments

The value of marginal product for research is estimated as per Equation (6):

$$EVMP\ (RES\_STOK) = b_i\ (V/RES\_STOK) \quad \ldots(6)$$

where, V is the value of crop production associated with TFP (value of output for crop multiplied by the share of TFP in total output), RES_STOK is the research stock and $b_i$ is the TFP elasticity of research stock estimated from TFP models 1 and 2. The benefit stream was generated under the assumption that the investment made in research in the year t–i will start generating a benefit after a lag of five years, at an increasing rate during the next nine years, will remain constant for the next nine years and thereafter, it will start declining. Following Evenson and Pray (1991), an investment of one rupee in the year t–i will generate a benefit equal to 0.1 EVMP in the year t–i+6, 0.2 EVMP in the year t–i+7, …..so on till t–i+13, and it will be 0.9 EVMP in the year t–i+14. After this, the benefit will be equal to EVMP up to the year t–i+23. Then, the benefit from the year t–i+24 onwards will again start declining and will be equal to 0.9 EVMP in the year t–i+24, and 0.8 EVMP in the year t–i+25, and so on. This benefit stream can then be discounted at the rate, say ‘r’, at which the present value of the benefit is equal to one. Thus, ‘r’ was considered as the marginal internal rate of return to public research investment.

3

# Main Findings and Discussions

This chapter presents the results related to TFP at all-India level as well as at state level, followed by estimates of returns to investments in agricultural research and its contribution to attaining of self-sufficiency in the selected crops. The TFP estimates pertain to a period of about three decades, starting from the early years of the green revolution in the country. Accordingly, TFP analysis has covered the period from 1975-76 to 2005-06 (abbreviated as 1975-05). These three decades were further divided into three sub-periods, viz. 1975-76 to 1985-86 (abbreviated as 1975-85), 1986-87 to 1995-96 (abbreviated as 1986-95) and 1996-97 to 2005-06 (abbreviated as 1996-05).

## TFP Growth by Crops at National Level

The estimates of average annual TFP growth for the major crops cultivated in India are shown in Table 3.1. The input and output growths for each crop by decades is presented in Appendix 3. Among cereals, wheat experienced the highest growth in TFP index during the three decades from 1975 to 2005. The annual rate of growth in wheat TFP was 1.9%, compared to 1.4% for maize and barley, 1% for bajra, 0.7% for rice, and 0.6% for jowar.

The TFP growth (TFPG) in the oilseed sector varied in the range 0.7-0.8% per annum. Among pulses, the TFPG was estimated to be 0.5% for moong, followed by gram (0.2%). TFP for arhar and urad crops displayed a decline over the past three decades.

Among fibre crops, the TFP index has risen at the annual rate of 1.4% for cotton and 1.3% for jute during the period 1975-05. The TFP growth rates in sugarcane, onion and potato have been found negative (-0.4% to -0.7%). It is interesting to point out that TFP in the case of sugarcane increased during the decade of 1975-85 but declined in the next two decades. In the case of onion and potato, TFP improved during 1986-95, but declined thereafter.

The TFP is quite a useful indicator of changes in long-term productivity. However, it has also been used to indicate short-term trends, particularly to know the current status, though it could sometimes lead to wrong interpretation if the chosen period happens to be short. Accordingly, three decades of study period were divided into three phases of one decade

**Table 3.1. Annual growth rate in total factor productivity of various crops in India: 1975-2005**

**(in per cent)**

| Crop | 1975-85 | 1986-95 | 1996-05 | 1975-2005 |
|---|---|---|---|---|
| Rice | 0.90 | 0.74 | 0.40 | 0.67 |
| Wheat | 1.60 | 2.51 | 1.61 | 1.92 |
| Maize | 2.00 | 0.67 | 1.64 | 1.39 |
| Jowar | 1.15 | 0.74 | -0.42 | 0.63 |
| Bajra | 1.22 | 0.39 | 1.50 | 1.04 |
| Barley | 2.68 | 0.44 | 0.61 | 1.38 |
| Gram | 0.06 | 0.09 | 0.34 | 0.16 |
| Moong | NA | -0.59 | 1.70 | 0.53 |
| Arhar | NA | 0.21 | -0.54 | -0.69 |
| Urad | NA | -0.22 | -0.73 | -0.47 |
| Soybean | NA | 0.83 | 0.63 | 0.71 |
| Groundnut | 0.49 | 0.55 | 1.30 | 0.77 |
| Rapeseed and mustard | 1.88 | 0.74 | 0.08 | 0.79 |
| Sugarcane | 1.38 | -1.32 | -0.65 | -0.41 |
| Cotton | 2.84 | 0.92 | 0.80 | 1.41 |
| Jute | 1.88 | 1.59 | 0.25 | 1.28 |
| Onion | NA | 2.37 | -1.62 | -0.49 |
| Potato | NA | 1.20 | -1.28 | -0.76 |

NA = Data not available

each to ascertain changes in TFP over time and to get an idea about changes in TFP in a recent period, which is pertinent for addressing emerging concerns.

The results for different sub-periods have shown a mixed trend. The growth in TFP has improved in a few crops and deteriorated in some other crops. The TFP estimates for the period 1975-85 have indicated a significant growth for cereals, rapeseed and mustard, sugarcane, cotton and jute.

Except wheat and groundnut, TFPG during 1986-95 was lower than that of 1975-85 in all the crops. The TFPG was also found lower during 1996-05 as compared to TFPG in the first decade in the case of rice, maize, jowar, barley, rapeseed and mustard and all the cash crops. The TFP of wheat witnessed a substantial increase during 1986-95 with a growth rate of 2.51% per annum. Though growth in TFP followed a mixed pattern over time, there are some noteworthy changes:

- After mid-1990s, TFPG of maize and bajra witnessed a sharp increase.

- The growth in TFP of moong during this period was as high as 1.7% per annum, which is a complete reversal of TFP trend in the previous decade.
- Out of 18 crops selected for the study, three-fourths exhibited a decline in TFP after mid-1990s.
- The TFP of onion and potato declined by more than 1% per year after 1996.

Using the estimates of TFP growth, its share in output growth was estimated for the selected crops in different periods and for the total period 1975-05 (Table 3.2). These estimates were computed only for those cases where TFP growth was positive.

**Table 3.2. Share of TFP growth in output growth of various crops in India: 1975-2005**

**(in per cent)**

| Crop | 1975-85 | 1986-95 | 1996-05 | 1975-05 |
|---|---|---|---|---|
| **Cereals** | | | | |
| Rice | 21.0 | 23.5 | 43.5 | 24.6 |
| Wheat | 27.1 | 68.3 | 60.4 | 58.9 |
| Maize | 10.8 | 11.6 | 31.0 | 16.5 |
| Jowar | 16.4 | 47.7 | (-) | 23.7 |
| Bajra | 26.7 | 9.4 | 55.9 | 27.6 |
| Barley | 23.5 | 30.5 | (-) | 29.4 |
| **Pulses** | | | | |
| Gram | 1.2 | 5.7 | 71.4 | 26.1 |
| Moong | NA | (-) | 17.8 | 10.0 |
| Arhar | NA | 33.8 | (-) | (-) |
| Urad | NA | (-) | (-) | (-) |
| **Oilseeds** | | | | |
| Soybean | NA | 4.6 | 6.7 | 5.5 |
| Groundnut | 19.2 | 25.4 | 30.8 | 27.1 |
| Rapeseed & mustard | 17.1 | 8.0 | 7.7 | 10.1 |
| **Other crops** | | | | |
| Sugarcane | 21.6 | (-) | (-) | (-) |
| Cotton | 35.0 | 21.5 | 46.0 | 31.6 |
| Jute | 57.4 | 83.6 | 70.5 | 74.1 |

NA = Data not available

* For the crops where the new technology has not induced a higher use of inputs, the output growth is largely because of technology. Under such a situation, the share of TFP growth in output growth will reflect a higher share in comparison to those crops where the technology induces a higher use of inputs.

During the past three decades, the share of TFP growth in output growth is estimated to be 5% to 74% for various crops — the lowest being for soybean and the highest for jute*. More than 50% of increase in wheat output and 24% to 30% increase in the output of rice, jowar, bajra, barley, gram and groundnut could be possible through technological change.

Decade-wise data have shown that contribution of technology to output growth was substantially higher during the decade of 1996-05 than during the previous two decades. The contribution of TFP to output growth was higher during 1986-95 than during 1975-85 in the case of all foodgrains, except bajra.

The nominal cost per unit of crop output has shown an upward trend despite growth in productivity. However, this includes the effect of increase in nominal prices of farm inputs. In order to take care of inflation in the input prices, cost of production was estimated at constant prices of the

**Table 3.3. Annual growth rate in real cost of production (at 2005-06 prices) for various crops in India: 1975-2005**

**(in per cent)**

| Crop | 1975-85 | 1986-95 | 1996-05 | 1975-05 |
|---|---|---|---|---|
| **Cereals** | | | | |
| Rice | -1.05 | -2.07 | -0.02 | -1.01 |
| Wheat | -2.94 | -1.84 | -2.17 | -2.28 |
| Maize | -2.47 | -0.54 | -2.16 | -1.30 |
| Jowar | -3.71 | -0.96 | 0.44 | -2.06 |
| Bajra | -2.69 | -0.52 | -2.37 | -1.86 |
| Barley | -3.19 | -0.95 | -1.81 | -2.07 |
| **Pulses** | | | | |
| Gram | -1.32 | -0.72 | -0.98 | -1.01 |
| Moong | NA | -0.65 | -1.59 | -1.11 |
| Arhar | NA | -0.33 | 0.99 | 0.90 |
| Urad | NA | 0.78 | 1.08 | 0.14 |
| **Edible oilseeds** | | | | |
| Soybean | NA | -1.27 | -0.54 | -0.84 |
| Groundnut | -1.14 | -0.70 | -1.46 | -1.11 |
| Rapeseed & mustard | -2.88 | -1.65 | -1.64 | -1.99 |
| **Other crops** | | | | |
| Sugarcane | -2.20 | 0.66 | 0.19 | -0.36 |
| Cotton | -2.80 | -1.66 | -0.63 | -1.62 |
| Jute | -2.40 | -2.66 | -0.08 | -1.73 |

NA = Data not available

year 2005-06 using cost of production data available in various reports of Commission on Agricultural Cost and Prices. The annual growth rate in the real cost of production for the selected crops has been reported in Table 3.3.

The changes in TFP growth are the significant determinants of average cost of production and income. Accordingly, trend in real cost of production is expected to decline with increase in TFP, other things held constant. The per unit cost of cereal crops has shown annual decline in the range of 1.0 - 2.3%. The largest decline in the real cost per unit of output was witnessed in the case of wheat.

As was the case with TFP, the real cost of pulses production also showed an increase in arhar and urad and a decline in gram and moong. In case of edible oilseeds and other crops, the real cost of production showed an annual decline in the range of 0.36% to 1.99 %. The real cost of production of cereals and oilseeds kept falling during all the three sub-periods.

## TFP Growth for Major Crops by States

As the spread of technology and other factors affecting crop production varied across states and regions, the growth in TFP was also expected to vary accordingly. State-wise and crop-wise growth rates in TFP computed from the annual compound growth rates of input and output during the period 1975-2005 for major crops grown in different states of India have been presented in Tables 3.4 to 3.12. All the states with major contribution in production of different crops were included in the TFP analysis.

### Rice

The major rice-growing states in India are: West Bengal, Andhra Pradesh, Uttar Pradesh, Punjab, Orissa, Karnataka, Tamil Nadu, Haryana and Madhya Pradesh; these contribute more than two-thirds to the country's rice production. The average annual growth rates of input, output and TFP indices for rice are given in Table 3.4. The input index increased by 5% each year for three decades in the state of Punjab, which was the highest among all the states. Haryana ranked second (4.2%) and Karnataka ranked third (3.2%) in terms of growth in input-use in rice cultivation. Input growth in Madhya Pradesh, Uttar Pradesh, and West Bengal and Assam varied between 2% and 3%. Andhra Pradesh, Orissa, and Tamil Nadu showed around 1% annual increase in the use of all inputs, while Kerala witnessed a decline in input-use in rice.

**Table 3.4. Annual growth rates in input use, output, TFP and real cost of production (RCP) for rice in different states and regions of India: 1975-2005**

**(in per cent)**

| State and region | Input growth | Output growth | TFP growth | RCP growth | TFPG share in output growth |
|---|---|---|---|---|---|
| Andhra Pradesh | 1.13 | 2.67 | 1.54 | -1.87 | 57.7 |
| Assam | 1.72 | 2.39 | 0.68 | -1.38 | 28.3 |
| Bihar | 0.31 | 0.69 | 0.38 | -0.71 | 55.7 |
| Haryana | 4.17 | 4.50 | 0.33 | -0.77 | 7.4 |
| Karnataka | 3.26 | 3.30 | 0.04 | -0.43 | 1.3 |
| Madhya Pradesh | 2.37 | 2.54 | 0.17 | -0.52 | 6.5 |
| Orissa | 1.05 | 1.47 | 0.42 | -0.65 | 28.3 |
| Punjab | 5.01 | 7.31 | 2.30 | -2.54 | 31.4 |
| Tamil Nadu | 0.85 | 2.44 | 1.58 | -2.01 | 65.0 |
| Uttar Pradesh | 1.82 | 2.75 | 0.93 | -1.66 | 33.9 |
| West Bengal | 1.77 | 2.18 | 0.41 | -0.64 | 18.9 |
| Eastern region | 1.20 | 1.98 | 0.78 | -1.30 | 39.6 |
| Western region | 2.37 | 2.54 | 0.17 | -0.52 | 6.5 |
| Northern region | 2.39 | 3.82 | 1.43 | -1.59 | 37.4 |
| Southern region | 1.62 | 2.68 | 1.07 | -1.43 | 39.7 |

Due to increase in input-use and incorporation of technological change, rice output increased annually by 7.3% in Punjab, 4.5% in Haryana, 2-3% in Andhra Pradesh, Assam, Karnataka, Madhya Pradesh, Tamil Nadu, Uttar Pradesh, and West Bengal, 1.5% in Orissa, and 0.7% in Bihar. The TFP growth rate for rice was estimated to be less than 0.5% in six states (Karnataka, Madhya Pradesh, Haryana, Bihar, West Bengal and Orissa), 0.5-1% in two states (Assam and Uttar Pradesh), 1-2% in Andhra Pradesh and Tamil Nadu and more than 2% in Punjab only.

The contribution of TFP to output growth for rice varied from as high as 65% in Tamil Nadu to a meagre 1% in Karnataka and about 7% in Haryana and Madhya Pradesh. More than 50% of growth in the rice output in Tamil Nadu, Andhra Pradesh and Bihar is attributable to TFP and technological change. In the other states, increase in input-use has been the major source of growth in rice output. The northern region has shown the highest growth in TFP (1.43%), followed by southern region (1.07%), eastern region (0.78%), and minimum in the western region (0.17%). The western region has dragged the national average of TFPG in rice to 0.67%.

The case of Haryana in the northern region is somewhat puzzling; its performance has been in sharp contrast to that of Uttar Pradesh and the adjoining state of Punjab. It seems that increase in area under *basmati* rice in this state, which has lower yield than *non-basmati* varieties, has resulted in very small growth in contribution of TFP as the present TFP analysis did not account for quality characteristics of rice. For a realistic assessment of TFP growth, there is a need to collect variety-specific micro-level time series data for the crop in coordination with biological scientists.

## Wheat

Wheat is the second most important crop after rice in the country. The introduction and rapid spread of high-yielding varieties in 1970s resulted in a phenomenal growth in wheat output. Haryana, Madhya Pradesh, Punjab, Rajasthan and Uttar Pradesh are the main wheat-producing states, contributing more than 85% to the total wheat production in India. The TFP analysis for these main states and a few other important wheat-growing states is presented in Table 3.5.

**Table 3.5. Annual growth rates in input use, output, TFP and real cost of production (RCP) for wheat in different states of India: 1975-2005**

**(in per cent)**

| State | Input growth | Output growth | TFP growth | RCP growth | TFPG share in output growth |
|---|---|---|---|---|---|
| Bihar | 1.57 | 1.61 | 0.04 | -0.04 | 02.6 |
| Gujarat | 1.55 | 3.16 | 1.61 | -1.85 | 50.9 |
| Haryana | 3.26 | 4.26 | 1.00 | -2.08 | 23.5 |
| Himachal Pradesh | 2.39 | 0.34 | -2.05 | 0.74 | (-) |
| Madhya Pradesh | 2.66 | 3.24 | 0.59 | -1.57 | 18.1 |
| Punjab | 2.02 | 3.15 | 1.14 | -1.65 | 36.1 |
| Rajasthan | 1.80 | 2.60 | 0.81 | -1.33 | 30.9 |
| Uttar Pradesh | 0.87 | 2.64 | 1.77 | -1.43 | 66.9 |
| West Bengal | 0.52 | 0.69 | 0.17 | -0.52 | 24.7 |

The TFP index for wheat has shown an annual growth rate of 1.77% in Uttar Pradesh, followed by 1.6% in Gujarat, about 1% each in Punjab and Haryana, 0.8% in Rajasthan, and 0.6% in Madhya Pradesh. Thus, among the non-traditional wheat-growing states, Gujarat has shown an outstanding performance of TFP growth in wheat. The TFPG was very low in West Bengal, negligible for Bihar and negative for Himachal Pradesh.

## Maize

Andhra Pradesh has emerged as the fastest maize-growing state, contributing 21% to national maize production with 10% share in total maize area of the country. The yield of maize in Andhra Pradesh is almost double as compared to other major maize-growing states in the country. As shown in Table 3.6, the input index has increased at the rate of 8.5%, and output index at the rate of 11.6%, resulting in a notable TFP growth (2.9%) and 3.54% and decline in production cost per unit of maize at constant price.

**Table 3.6. Annual growth rates in input use, output, TFP and real cost of production (RCP) for maize in different states of India: 1975-05**

**(in per cent)**

| State | Input growth | Output growth | TFP growth | RCP growth | TFPG share in output growth |
|---|---|---|---|---|---|
| Andhra Pradesh | 8.50 | 11.62 | 2.88 | -3.54 | 24.8 |
| Bihar | 0.26 | 1.33 | 1.07 | -1.27 | 80.2 |
| Himachal Pradesh | 0.95 | 0.49 | -0.46 | 0.54 | (-) |
| Madhya Pradesh | 1.00 | 1.11 | 0.11 | -0.17 | 10.1 |
| Rajasthan | 2.83 | 2.43 | -0.39 | 0.18 | (-) |
| Uttar Pradesh | -2.09 | -1.26 | 0.85 | -1.06 | (-) |

The TFP growth constituted one-fourth of the growth in maize output in Andhra Pradesh and 80% in Bihar. In other frontline states, the performance of maize remained dismal. The technological contribution to maize production was stagnant in Madhya Pradesh and negative in Rajasthan and Himachal Pradesh, which points towards a threat to the economic viability of maize production. Though Uttar Pradesh has shown 0.85% annual growth in TFP, it is not meaningful as it is associated with a negative input-output growth.

## Jowar

Maharashtra is the major state for jowar production in India, contributing more than half of the national production, with 54% of the total jowar area. During the past three decades, input-use in jowar in Maharashtra has increased at the rate of 1.9% and output index has increased by 2.9%, involving close to 1% growth in TFP (Table 3.7).

The share of technology in output growth of jowar was estimated as 32% in Maharashtra. The state of Karnataka ranked second in jowar

**Table 3.7. Annual growth rates in input use, output, TFP and real cost of production (RCP) for jowar in different states of India: 1975-2005**

**(in per cent)**

| State | Input growth | Output growth | TFP growth | RCP growth | TFPG share in output growth |
|---|---|---|---|---|---|
| Andhra Pradesh | -1.91 | -0.60 | 1.32 | -2.12 | (-) |
| Karnataka | 1.97 | 1.81 | -0.16 | 0.12 | (-) |
| Madhya Pradesh | -1.79 | -2.83 | -1.03 | 0.58 | (-) |
| Maharashtra | 1.95 | 2.86 | 0.91 | -3.19 | 31.8 |
| Rajasthan | 3.33 | 3.01 | -0.32 | 0.83 | (-) |
| Tamil Nadu | -1.03 | -0.44 | 0.59 | -0.51 | (-) |

production, with its share of 21% in the country. The rise in input-use at the rate of 1.97% has raised the output index merely by 1.81%, which has resulted in a negative TFP growth for jowar in Karnataka. A similar pattern was observed for Rajasthan. The TFP growths in Andhra Pradesh and Tamil Nadu were positive and moderate, even though there was a decline in the input-use index.

## Bajra

Rajasthan, Uttar Pradesh, Gujarat, Maharashtra and Haryana are the major bajra-growing states. They contributed 87% to the total bajra production in the country. The performance of technological change in bajra crop was in sharp contrast to that of maize and jowar. The TFP growth ranged between 2% and 3% in Mahrashtra, Gujarat, Tamil Nadu and Rajasthan, which is considered high. Haryana experienced a moderate growth and Uttar Pradesh showed a low growth in TFP of bajra (Table 3.8).

**Table 3.8. Annual growth rates in input use, output, TFP and real cost of production (RCP) for bajra in different states of India: 1975-2005**

**(in per cent)**

| State | Input growth | Output growth | TFP growth | RCP growth | TFPG share in output growth |
|---|---|---|---|---|---|
| Gujarat | -0.42 | 1.97 | 2.39 | -2.37 | — |
| Haryana | -0.08 | 1.25 | 1.33 | -0.98 | — |
| Maharashtra | 0.88 | 3.83 | 2.95 | -3.17 | 78.29 |
| Rajasthan | 2.79 | 4.94 | 2.15 | -4.17 | 43.5 |
| Tamil Nadu | -6.91 | -4.65 | 2.26 | -2.28 | — |
| Uttar Pradesh | 0.05 | 0.70 | 0.65 | -0.65 | 93.2 |

The spread of hybrid varieties has been the main factor for input saving and output growth in bajra production in these states.

It is important to mention that in some cases input-use in bajra showed a decline while its output increased. Such changes lead to positive growth in TFP. Similarly, in some cases, the rate of decrease in input index was higher than the rate of decrease in output, which translated into a positive growth in TFP. These types of TFP growth are not meaningful and may be due to spatial shift in area under crops or inward movement on the production function. The share of TFP growth in output growth in such cases has not been reported in the study.

## Pulses

The annual growths in input, output and TFP indices for major pulses, namely, gram, arhar, moong, and urad grown in different states of India, are given in Table 3.9.

A perusal of Table 3.9 reveals a widespread decline in input-use as well as output of pulses. This could be due to the shifting of pulses cultivation to marginal lands. No technological gains were experienced for gram in Rajasthan; for arhar in Uttar Pradesh, Tamil Nadu and Orissa; for moong in Madhya Pradesh, Maharashtra, and Orissa; and for urad in Madhya Pradesh, Orissa, and Tamil Nadu.

A few states performed well and have benefited from the adoption of improved technology. These are: Andhra Pradesh, Maharashtra, and Karnataka for arhar; Rajasthan and Andhra Pradesh for moong; and Andhra Pradesh, Rajasthan and Uttar Pradesh for urad.

In a number of states, the TFP growth has been positive coupled with negative growth in input-use. This does not imply any technological change as the same could result due to downward movement on a production function. Technology and managerial inputs have contributed to meaningful TFP growths for gram in Madhya Pradesh, moong in Rajasthan and Andhra Pradesh, arhar in Andhra Pradesh, Karnataka, and Maharashtra and urad in Rajasthan, Andhra Pradesh, and Uttar Pradesh. The states witnessing a positive growth in TFP, have experienced a decline in per unit real cost of production and this decline has been quite substantial in some states.

## Edible Oilseeds

Rapeseed and mustard (R&M), groundnut and soybean are the major oilseed crops grown in India. Rajasthan contributed nearly 54% to the

**Table 3.9. Annual growth rates in input use, output, TFP and real cost of production (RCP) for pulses in different states of India: 1975-2005**

**(in per cent)**

| State | Input growth | Output growth | TFP growth | RCP growth | TFPG share in output growth |
|---|---|---|---|---|---|
| | | | **Gram** | | |
| Bihar | -8.58 | -6.51 | 2.07 | -2.19 | (-) |
| Haryana | -4.31 | -3.14 | 1.17 | -2.56 | (-) |
| Madhya Pradesh | 2.62 | 2.99 | 0.38 | -1.00 | 12.6 |
| Maharashtra | 12.4 | 12.6 | 0.1 | 0.7 | 1.2 |
| Rajasthan | -1.97 | -2.57 | -0.59 | -0.81 | (-) |
| Uttar Pradesh | -3.04 | -2.53 | 0.52 | -1.15 | (-) |
| | | | **Moong** | | |
| Andhra Pradesh | 0.76 | 2.13 | 1.36 | -3.06 | 64.2 |
| Madhya Pradesh | -3.08 | -5.48 | -2.40 | 0.75 | (-) |
| Maharashtra | 29.50 | 28.04 | -1.46 | 0.05 | (-) |
| Orissa | -5.66 | -6.85 | -1.19 | 1.03 | (-) |
| Rajasthan | 8.64 | 11.78 | 3.14 | 1.00 | 26.7 |
| | | | **Arhar** | | |
| Andhra Pradesh | 1.51 | 3.69 | 2.18 | -2.14 | 59.1 |
| Gujarat | -0.02 | 0.83 | 0.85 | -0.97 | NA |
| Karnataka | 1.56 | 2.52 | 0.97 | -0.77 | 38.3 |
| Madhya Pradesh | -2.11 | -1.07 | 1.04 | -1.25 | (-) |
| Maharashtra | 6.46 | 7.47 | 1.00 | -1.13 | 13.4 |
| Orissa | -1.92 | -2.85 | -0.94 | 0.65 | (-) |
| Tamil Nadu | -2.62 | -12.12 | -9.49 | 9.36 | 78.4 |
| Uttar Pradesh | -1.17 | -2.28 | -1.12 | 0.31 | (-) |
| | | | **Urad** | | |
| Andhra Pradesh | 3.78 | 4.83 | 1.05 | -1.10 | 21.8 |
| Madhya Pradesh | -1.38 | -4.76 | -3.38 | 2.82 | (-) |
| Mahrashtra | 3.89 | 3.96 | 0.07 | 0.09 | 1.8 |
| Orissa | -9.45 | -10.93 | -1.48 | 1.36 | (-) |
| Rajasthan | 1.6 | 5.0 | 3.3 | -5.5 | 66.4 |
| Tamil Nadu | 3.87 | 2.55 | -1.32 | 0.89 | (-) |
| Uttar Pradesh | 1.65 | 2.58 | 0.93 | -0.90 | 36.1 |

**Table 3.10. Annual growth rates in input use, output, TFP and real cost of production (RCP) for edible oilseeds grown in different states of India: 1975-2005**

**(in per cent)**

| State | Input growth | Output growth | TFP growth | RCP growth | TFPG share in output growth |
|---|---|---|---|---|---|
| **Rapeseed & mustard** | | | | | |
| Assam | 1.05 | 1.70 | 0.65 | -1.18 | 38.1 |
| Gujarat | 1.33 | 4.57 | 3.24 | -4.36 | 70.9 |
| Haryana | 7.00 | 6.85 | -0.16 | 0.32 | (-) |
| Madhya Pradesh | 10.20 | 12.34 | 2.14 | -3.84 | 17.3 |
| Punjab | -3.18 | -3.88 | -0.71 | 0.45 | (-) |
| Rajasthan | 7.00 | 8.25 | 1.25 | -2.63 | 15.2 |
| Uttar Pradesh | 1.28 | 1.48 | 0.20 | -1.11 | 13.5 |
| West Bengal | 2.18 | -0.71 | -2.89 | 1.40 | (-) |
| **Groundnut** | | | | | |
| Andhra Pradesh | 3.45 | 4.86 | 1.41 | -1.77 | 29.0 |
| Gujarat | 1.14 | 2.46 | 1.32 | -1.28 | 53.6 |
| Karnataka | 2.35 | 2.13 | -0.22 | 0.21 | (-) |
| Maharashtra | -3.31 | -2.39 | 0.92 | -1.27 | (-) |
| Orissa | 5.39 | 7.49 | 2.10 | -2.74 | 28.1 |
| Tamil Nadu | -0.84 | -1.27 | -0.42 | 0.44 | (-) |
| **Soybean** | | | | | |
| Madhya Pradesh | 11.35 | 11.81 | 0.47 | -0.67 | 4.0 |
| Maharashtra | 15.35 | 15.10 | -0.25 | 0.54 | (-) |
| Rajasthan | 4.03 | 4.56 | 0.54 | -0.77 | 11.7 |
| Uttar Pradesh | 6.02 | 7.03 | 1.01 | - 1.27 | 14.4 |

total R&M production, Gujarat's share in national groundnut production was nearly 42%, and Madhya Pradesh produced 55% of the national soybean output. The average annual growth rates of input, output and TFP indices for edible oilseeds are given in Table 3.10.

## Rapeseed and Mustard

The best performance of rapeseed and mustard production during 1975-2005 was found in Gujarat where output followed the annual growth of 4.57%, led primarily by technological improvement. In fact, the growth in output was highest in Madhya Pradesh, but more than 80% of this growth was due to increased use of inputs. The input index for R&M in Rajasthan increased at the rate of 7% during 1975-2005, while output showed an annual increase of 8.3%. This led to 1.3% annual growth in TFP and 2.6% reduction in per unit cost of production at constant price. Technological change contributed 15% growth to output in Rajasthan. The states of Haryana and West Bengal have shown a lower growth in output as compared to the growth in input, indicating a deterioration in TFP.

### Groundnut

In Gujarat, the growth rates in input, output and TFP for groundnut were estimated as 1.1%, 2.5% and 1.3%, respectively. Orissa has shown an outstanding performance in output growth besides high growth in input-use, which led to 2.1% annual growth in TFP. The TFP growth was found responsible for 28% of the growth in output. A moderate TFP growth has been observed in Andhra Pradesh. The groundnut production in Karnataka and Tamil Nadu is heading towards un-sustainability, but other states have shown moderate to high growth in TFP.

### Soybean

For soybean, high growths in inputs and crop production were observed in all the states under study. Despite high growths in input and output, the TFP growth has been assessed low (0.5%) in Madhya Pradesh and Rajasthan, moderate in Uttar Pradesh and negative in Maharashtra. Thus, the soybean output growth has been mainly input-based, which may not be sustained in future in the absence of input-saving varieties and technologies.

## Fibre Crops

### Cotton

Gujarat, Maharashtra, Andhra Pradesh, Punjab and Haryana are the major cotton-producing states, contributing nearly 85% to the national production of cotton. The results related to input, output and TFP growths are presented in Table 3.11.

The TFP index for cotton in Andhra Pradesh during 1975-2005 has risen at the rate of 2.1%, whereas it was 1.4% in Maharashtra, 1.3% in Gujarat, 0.8% in Haryana and 0.5% in Punjab. The total factor productivity growth or technological change has been responsible for 15% to 46% of the total output growth. The input-use growth had contributed more

**Table 3.11. Annual growth rates in input use, output, TFP and real cost of production (RCP) for fibre crops grown in different states of India: 1975-2005**

**(in per cent)**

| State | Input growth | Output growth | TFP growth | RCP growth | TFPG share in output growth |
|---|---|---|---|---|---|
| **Cotton** | | | | | |
| Andhra Pradesh | 2.81 | 4.95 | 2.13 | -2.16 | 43.1 |
| Gujarat | 1.46 | 2.74 | 1.27 | -0.55 | 46.4 |
| Haryana | 4.76 | 5.59 | 0.83 | 0.29 | 14.8 |
| Maharashtra | 2.93 | 4.36 | 1.43 | -2.62 | 32.9 |
| Punjab | 1.95 | 2.41 | 0.46 | -0.64 | 19.2 |
| Tamil Nadu | -0.36 | 0.37 | 0.72 | -1.70 | — |
| **Jute** | | | | | |
| Assam | 0.64 | 0.95 | 0.31 | -0.86 | 30.2 |
| Bihar | 0.63 | 1.90 | 1.27 | -2.14 | 66.8 |
| Orissa | 0.63 | 2.61 | 1.98 | -5.20 | 75.9 |
| West Bengal | 1.51 | 3.07 | 1.57 | -0.83 | 51.0 |

substantially than technology to the supply of cotton in the country till 2005. This situation might have changed after 2005 due to widespread adoption of Bt cotton in the country.

## Jute

West Bengal is the dominant state for jute production, contributing 80% to the national production. Bihar ranked second in jute production, followed by Assam and Orissa. The growth in input-use ranged from merely 0.6% to 1.5%. The output growth has been contributed mainly by improvement in TFP. The states of West Bengal, Bihar and Orissa have depicted high TFP growths, in the range of 1.3% to 1.9%, whereas, TFP growth has been estimated as only 0.3% in Assam. About one-third output growth was contributed by TFP in Assam. More than half of the output growth was contributed by TFP in the other jute-producing states.

## Sugarcane

The annual growth in input use, sugarcane production and TFP indices reveal that the input growth was much higher than the output growth, resulting in a negative TFP growth for all the states (Table 3.12). This is a sign of non-sustainability of sugarcane production in the country. The unit cost of sugarcane production has also been increasing in all the states. It implies that profitability of sugarcane production is maintained because of the output price increases which is not sustainable. Undoubtedly,

**Table 3.12. Annual growth rates in input use, output, TFP and real cost of production (RCP) for sugarcane in different states of India: 1975-2005**

**(in per cent)**

| State | Input growth | Output growth | TFP growth | RCP growth | TFPG share in output growth |
|---|---|---|---|---|---|
| Andhra Pradesh | 3.08 | 1.33 | -1.75 | 1.14 | (-) |
| Bihar | 4.01 | 2.63 | -2.39 | 0.43 | (-) |
| Haryana | 5.15 | 3.28 | -1.88 | 2.51 | (-) |
| Karnataka | 6.65 | 3.96 | -2.69 | 2.68 | (-) |
| Maharashtra | 4.82 | 3.12 | -1.70 | 0.72 | (-) |
| Tamil Nadu | 2.74 | 1.53 | -1.21 | 0.07 | (-) |
| Uttar Pradesh | 3.26 | 2.89 | -0.37 | 0.47 | (-) |

research and extension efforts should be the priority to enhance productivity gains in sugarcane production. This can be achieved by the efficient use of inputs along with development of new varieties and transfer of technology to farmers.

## Prioritization of States for Research Resource Allocation

To identify the states that should be accorded higher priority for resource investment to raise their crop productivity and address the issues of technological progress and sustainability, various states were classified into five groups according to the magnitude of growth in TFP, as under:

| | | |
|---|---|---|
| Negative growth | : | TFP growth less than zero |
| Stagnant growth | : | TFP growth positive but less than 0.5% |
| Low growth | : | TFP growth of 0.5-1% |
| Moderate growth | : | TFP growth of >1.0-2.0% |
| High growth | : | TFP growth of more than 2% |

The distribution of various states in TFP growth categories for different crops is shown in Table 3.13. In the case of bajra, cotton and jute, all the selected states have witnessed a moderate to high improvement in TFP. Similarly, TFP growth in wheat was found positive in all states, except Himachal Pradesh. In the case of jowar, half of the states have shown low to moderate growth in TFP and the remaining states have depicted a decline in TFP. About one-third of the selected states have experienced a fall in TFP in pulse crops. In rice, a large number of states have

**Table 3.13. Trends in total factor productivity growths in various crops in selected states of India: 1975-2005**

| Crops | Total factor productivity growth category | | | | |
|---|---|---|---|---|---|
| | Positive | | | | Negative |
| | < 0.5% (Stagnant growth) | 0.5-1% (Low growth) | >1-2% (Moderate growth) | >2% (High growth) | |
| | **Cereals** | | | | |
| Rice | KN, MP, HY BH, OR, WB | AS, KR, UP | AP, TN | PB | |
| Wheat | BH, WB | MP, RJ | HY, PB, GJ, UP | | HP |
| Maize | MP | UP | BH | AP | HP, RJ |
| Jowar | | TN | MH, AP | | MP, RJ, KN |
| Bajra | | UP | HY | RJ, TN, GJ, MH | |
| | **Pulses** | | | | |
| Gram | MH, MP, UP | | HY | BH | RJ |
| Moong | | | AP | RJ | MP, MH, OR |
| Arhar | | GJ, KN | MH, MP | AP | TN, UP, OR |
| Urad | MH | UP | AP | RJ | MP, OR, TN |
| | **Oilseeds** | | | | |
| Rapeseed & mustard | UP | AS | RJ | MP | WB, PB, HY |
| Groundnut | | | MH, GJ, AP | OR | TN, KN |
| Soybean | | MP, RJ | UP | | MH |
| **Cash crops** | | | | | |
| Sugarcane | | | | | BH, KN, HY, AP, MH, TN, UP |
| | **Fibre crops** | | | | |
| Cotton | PB | HY | GJ, MH | AP | |
| Jute | AS | WB, OR, BH | | | |

*Notes:* AP: Andhra Pradesh, AS: Assam, BH: Bihar, GJ: Gujarat, HP: Himachal Pradesh, HY: Haryana, KN: Karnataka, KR: Kerala, MP: Madhya Pradesh, MH: Maharashtra, OR: Orissa, PB: Punjab, RJ: Rajasthan, TN: Tamil Nadu, UP: Uttar Pradesh, WB: West Bengal

depicted low growth in TFP; only Punjab has shown high TFP growth while Andhra Pradesh and Tamil Nadu have shown moderate growth in TFP. However, Bihar, Rajasthan and Andhra Pradesh have witnessed a high growth in TFP in pulses. Out of the sixteen states for which information was available in respect of oilseeds, TFP was found negative in six states, namely West Bengal, Punjab, Haryana, Tamil Nadu, Karnataka and

Maharashtra. As already mentioned, all the seven states selected for sugarcane study, have experienced deterioration in its TFP.

The results relating to TFP growth indicate that much technological gains have not been experienced in a number of crops in many states as they have shown a negative, stagnant or poor growth in the total factor productivity. Only a few states have shown outstanding performance of productivity growth and technological change which has moved the average productivity gain at the country level to a comfortable position, leading to the impression that technological gains have taken place in almost all the crops at the country level. The disaggregate analysis has also shown that a number of states and crops did not witness any technological progress. Therefore, priority must be focussed on those states which have been observed to be under the negative TFP growth or stagnant TFP growth. If the sustainability issue of crop system as implied by the TFP trend, is not addressed properly, it will adversely affect the long-term growth in agriculture as well as the national food security and household nutritional security.

## Distribution of Crop Area according to TFP Growth

Wide gaps exist in the adoption and performance of technology across states and crops due to large variations in soil fertility, availability of groundwater resources, climatic conditions, infrastructural development, generation and dissemination of technology, policy measures, etc. Accordingly, wide variations have been observed in TFP growth also across regions and crops, and these have important implications for the sustainability of growth process in the crop sector. An attempt was made to construct TFP growth index for the total crop sector based on the distribution of area and TFP growth of selected crops. This was done by assigning scores of 0 to 4 to different TFP growth categories and using crop-share in area as the weight. The states were further ranked based on the weighted growth rate of TFP score with the highest TFP growth score equated to 100. The estimates for the 16 major states of India are presented in Table 3.14.

Punjab, Gujarat, and Andhra Pradesh have been found to fall under high total factor productivity status with almost 90% or more cropped area experiencing moderate to high growth in TFP (more than 1%). About 60% area in Rajasthan witnessed more than 1% growth in TFP. Tamil Nadu, Haryana, Uttar Pradesh, and Maharashtra states have experienced low to high TFP growth, the cropped area being distributed across all TFP growth classes. The other states, viz. Madhya Pradesh,

**Table 3.14. Distribution of gross crop area according to TFP growth and its index by states in India: 1975-05**

| State | TFP growth class | | | | | Index of TFP growth score | |
|---|---|---|---|---|---|---|---|
| | Negative | < 0.5 (Stagnant growth) | 0.5-1.0 (Low growth) | >1.0-2.0 (Moderate growth) | > 2.0 (High growth) | Value | Rank |
| Punjab | 0.6 | 9.5 | 0.0 | 53.9 | 35.9 | 100.0 | 1 |
| Gujarat | 2.3 | 0.0 | 3.7 | 70.0 | 24.0 | 99.5 | 2 |
| Andhra Pradesh | 2.3 | 0.0 | 0.0 | 85.4 | 12.3 | 96.9 | 3 |
| Rajasthan | 23.4 | 0.0 | 16.9 | 20.1 | 39.6 | 80.2 | 4 |
| Tamil Nadu | 24.0 | 0.0 | 0.0 | 74.3 | 1.7 | 72.9 | 5 |
| Haryana | 10.1 | 18.6 | 11.3 | 60.0 | 0.0 | 70.2 | 6 |
| Uttar Pradesh | 11.9 | 6.2 | 34.4 | 47.5 | 0.0 | 69.1 | 7 |
| Maharashtra | 13.0 | 2.9 | 50.4 | 29.2 | 4.5 | 66.4 | 8 |
| Assam | 0.0 | 3.0 | 97.0 | 0.0 | 0.0 | 62.5 | 9 |
| Madhya Pradesh | 15.1 | 55.5 | 25.0 | 2.1 | 2.4 | 38.5 | 10 |
| West Bengal | 4.8 | 87.0 | 0.0 | 8.2 | 0.0 | 35.4 | 11 |
| Bihar | 5.0 | 90.3 | 0.0 | 2.0 | 2.7 | 34.0 | 12 |
| Orissa | 6.2 | 89.9 | 0.0 | 0.0 | 3.9 | 33.5 | 13 |
| Kerala | 28.6 | 71.4 | 0.0 | 0.0 | 0.0 | 22.7 | 14 |
| Karnataka | 67.5 | 17.2 | 6.9 | 0.0 | 8.5 | 20.6 | 15 |
| Himachal Pradesh | 46.1 | 53.9 | 0.0 | 0.0 | 0.0 | 17.1 | 16 |
| All states | 7.7 | 1.3 | 53.3 | 37.7 | 0.0 | 70.1 | - |

West Bengal, Bihar, Orissa, Kerala, Karnataka, and Himachal Pradesh have shown relatively low performance in productivity growth and a large share of their cropped area fell under negative, stagnant or poor productivity category.

The state of Punjab topped in the TFP growth score index (100). For other states, the score indices varied from 17.1 for Himachal Pradesh to 99.5 for Gujarat. This shows that technology-driven growth was highest in Punjab and lowest in Himachal Pradesh.

The TFP growth score of the crop sector in Gujarat, Andhra Pradesh, Rajasthan, and Tamil Nadu was higher than the all-India index, whereas for the states of Uttar Pradesh, Maharashtra, Assam, Madhya Pradesh, West Bengal, Bihar, Orissa, Kerala, Karnataka and Himachal Pradesh, it remained below the average value of the country. The index for the state of Haryana was almost same as the all-India average index. Based on this, it can be concluded that the states of Madhya Pradesh, West Bengal, Bihar, Orissa, Kerala, Karnataka and Himachal Pradesh must receive a higher priority in the research resource allocations, infrastructural development and technology generation and dissemination to improve the sustainability of their respective growth processes.

## Sources of Total Factor Productivity

The growth rate in TFP was further analysed in terms of contribution of various factors to TFP growth. The estimated effect of various factors which included research stock, extension stock, natural resource management, infrastructure, literacy, etc. on TFP for various crops under study has been presented in Appendix 5.1. The direction of statistically significant effect on TFP is presented in Table 3.15. The results reveal that the public investment in research constituted a significant source of TFP growth in all the crops, except moong, urad, sugarcane and jute. Public investment in the transfer of technology (extension) has contributed positively towards TFP enhancement in pulses and sugarcane. Natural resource management and infrastructure variables are important sources of TFP for most of the crops. Among natural resources, a reliable supply of irrigation revealed by the share of groundwater in total irrigation along with balanced use of fertilizers, have played a significant role in enhancing the TFP. A look at infrastructural variables revealed that road density and electricity supply have been the most significant determinants of TFP. This information is of crucial importance for researchers and policymakers in prioritising the investment decisions (Fan *et al*., 1999).

**Table 3.15. Direction of sources of TFP growth for various crops in India: 1975-2005**

| Crop | Model 1 | Model 2 |
|---|---|---|
| Rice | Research (+)<br>NARI (+)<br>Infrastructure (+)<br>Electricity (-) | Research (+)<br>$N:P_2O_5$ ratio (+)<br>Road (+) |
| Wheat | Research (+)<br>Extension (-)<br>Cropping intensity (+)<br>Road (+) | Research (+)<br>Extension (-) |
| Maize | Research (+)<br>NARI (+)<br>Infrastructure (-) | Research (+)<br>$N: P_2O_5$ ratio (+)<br>Electricity (-) |
| Jowar | Research (+)<br>Literacy (-) | Research (+)<br>Literacy (-) |
| Bajra | Research (+)<br>Literacy (+)<br>Infrastructure (+)<br>Road (+) | Research (+)<br>Literacy (+)<br>Groundwater (-) |
| Gram | Research (+)<br>Extension (+)<br>Cropping intensity (+)<br>Groundwater (+) | Research (+)<br>Extension (+) |
| Arhar | Research (+)<br>Literacy (-)<br>NARI (+)<br>Infrastructure (-)<br>Electicity (-) | Research (+)<br>Literacy (-)<br>Cropping intensity (+)<br>$N: P_2O_5$ ratio (+) |
| Moong | Extension (+)<br>Literacy (+)<br>Infrastructure (-) | Extension (+)<br>Road (+)<br>Electicity (-) |
| Urad | Extension (+)<br>Cropping intensity (+) | Extension (+) |
| Groundnut | Research (+)<br>Cropping intensity (+) | Research (+) |
| Rapeseed & mustard | Research (+) | Research (+) |
| Sugarcane | Extension(+)<br>Literacy (-) | Extension(+) |
| Cotton | Research (+)<br>Literacy (+)<br>NARI (-)<br>Groundwater (-)<br>Road (+) | Research (+)<br>Literacy (+)<br>$N: P_2O_5$ ratio (-) |
| Jute | NARI (+)<br>Infrastructure (+) | Cropping intensity (+) |

NARI=Natural agricultural resources index

The allocation of additional resources for research, road network, groundwater irrigation, etc. for crops and for states where the current yields are below the national average due to technological stagnation or decline, as identified in the study, is needed on a higher priority. Public investment in agricultural extension services has not turned up an important source of TFP growth for a number of crops. One of the reasons for this could be suboptimal investment below the critical level, as the ratio of amount spent on agricultural extension to that on research has been falling (Kumar, 2001). As a vast untapped yield potential exists in the country and India is in the process of development of the second-generation technologies, much more intensive efforts are required in extension services to disseminate the improved technology. The slowing down of emphasis on extension services in agriculture will further widen the gap in the adoption and generation of technology and will induce movement of cropped area towards negative growth or stagnation in TFP. Agricultural extension services need to be strengthened by scaling-up investment levels and by improving their quality. Road density would induce input-output market interface and create a suitable environment for the adoption of technology as well as induction of investments in agriculture.

Estimates of regression coefficients which measure the effect of various sources of TFP, were used to compute elasticity of TFP with respect to research stock and to assess the impact of research. TFP elasticity with respect to research stock ranged from 0.0185 for groundnut to 0.1933 for arhar (Table 3.16). The inverse of this elasticity gives research stock flexibility which represents the required increase in research stock to increase in TFP by 1%. These estimates show that to achieve 1% increase in TFP, the investments in research need be to increased by 21.5% for rice, 19.5% for wheat, 19.3% for bajra, 13.6% for maize, and 8.7% for jowar per annum. Among pulses, the research investments need to be increased by 5.2% for arhar and 10.7% for gram per annum. For edible oilseeds, research investments should be increased by 21.4% for R&M and by 54% for groundnut to achieve 1% growth in TFP. For cotton, investment will have to be raised by 12.7% per annum to increase 1% TFP. These results suggest a substantial raise in research investments in agriculture to maintain a steady growth rate in TFP. On an average, the investments on research in agriculture need an increase of about 25% per annum to achieve 1% growth in TFP.

To achieve 4% growth in agriculture, as targetted by the Planning Commission, a recent study has suggested to lay higher emphasis on the development of livestock, horticulture and fishery sectors besides crop sector. To attain this growth of 4%, the study has suggested that

**Table 3.16. Elasticity of TFP with respect to research stock for major crops in India**

| Crop | TFP elasticity with respect to research stock | | | Research stock flexibility |
|---|---|---|---|---|
| | Model 1 | Model 2 | Average | |
| Rice | 0.0454 | 0.0469 | 0.0465 | 21.5 |
| Wheat | 0.0513 | 0.0514 | 0.0513 | 19.5 |
| Maize | 0.0728 | 0.0743 | 0.0734 | 13.6 |
| Jowar | 0.1128 | 0.1183 | 0.1155 | 8.7 |
| Bajra | 0.0514 | 0.0524 | 0.0519 | 19.3 |
| Gram | 0.0986 | 0.0884 | 0.0935 | 10.7 |
| Arhar | 0.2148 | 0.1717 | 0.1933 | 5.2 |
| Groundnut | 0.0178 | 0.0192 | 0.0185 | 54.1 |
| Rapeseed & mustard | 0.0429 | 0.0505 | 0.0467 | 21.4 |
| Cotton | 0.0716 | 0.0857 | 0.0786 | 12.7 |

*Note:* Regression model 1 and model 2 have been specified in methodology section.

investments on agricultural research need to be doubled by 2015 and tripled by 2020 in relation to the investment level of 2002 (Mruthyunjaya and Kumar, 2010).

## Returns to Investment on Agricultural Research

### Value of Marginal Product

The estimated value of marginal product (EVMP) of research investment is presented in Table 3.17. The results revealed that additional investment of rupee one in research generated more than Re 1 on an average in all the crops, except groundnut and rapeseed & mustard during the period 1975 to 2005. Highest marginal product of research was achieved in arhar where additional investment of Re 1 generated additional output worth Rs 12.82.

Returns to research investments in foodgrains were found higher during 1995-2005 than during 1975-85. The marginal productivity of research investments in oilseeds declined sharply during 1995-2005. The value of marginal product less than “1” indicates that research in that commodity has not been generating enough output to justify investment. There is a need to change the focus of research in such crops to get higher returns from research investments.

**Table 3.17. Estimated value of marginal product of research stock in different crops in India: 1975-2005**

**(in Rupees)**

| Crop | 1975-85 | 1985-95 | 1995-05 | 1975-05 |
|---|---|---|---|---|
| Rice | 2.01 | 1.80 | 2.25 | 2.02 |
| Wheat | 2.86 | 5.78 | 3.45 | 4.03 |
| Maize | 1.63 | 1.40 | 2.53 | 1.85 |
| Jowar | 3.80 | 3.05 | 5.98 | 4.28 |
| Bajra | 2.85 | 0.80 | 3.23 | 2.29 |
| Gram | 0.23 | 0.88 | 7.42 | 2.84 |
| Arhar | 13.42 | 10.78 | 14.26 | 12.82 |
| Groundnut | 0.73 | 0.78 | 0.63 | 0.71 |
| Rapeseed & mustard | 1.64 | 0.62 | 0.40 | 0.89 |
| Cotton | 5.65 | 2.79 | 4.02 | 4.15 |

## Internal Rate of Return

The internal rate of return (IRR) to research investment for crops where the research stock coefficient in TFP decomposition equations was statistically significant was estimated following the assumption given in the methodology section and the results are presented in Table 3.18.

During the period 1975-2005, the overall internal rates of return to public agricultural research investment turned out to be 29% for rice, 38% for wheat, 28% for maize, 39% for jowar, 31% for bajra, 34% for gram, 57% for arhar, 18% for groundnut, 20% for R&M, and 39% for cotton. The rate of return to research investment was higher during 1995-05 than during 1985-95 in all the crops, except wheat and oilseeds. The

**Table 3.18. Estimated marginal internal rate of return to research investment in different crops in India: 1975-2005**

**(in per cent)**

| Crop | 1975-85 | 1985-95 | 1995-05 | 1975-05 |
|---|---|---|---|---|
| Rice | 29 | 28 | 31 | 29 |
| Wheat | 34 | 44 | 36 | 38 |
| Maize | 27 | 25 | 32 | 28 |
| Jowar | 37 | 34 | 44 | 39 |
| Bajra | 34 | 19 | 35 | 31 |
| Gram | 9 | 20 | 48 | 34 |
| Arhar | 58 | 54 | 59 | 57 |
| Groundnut | 18 | 19 | 17 | 18 |
| Rapeseed & mustard | 27 | 17 | 13 | 20 |
| Cotton | 43 | 33 | 38 | 39 |

results suggest that further investments on research in agriculture will generate significant returns and lead to development of agriculture in India.

## Sectoral Impact of Investments on Agricultural Research

The crops considered in the study accounted for 41 % share in the value of crop sector and 31% in the value of agricultural output, including both crop and livestock sectors, in the year 2005-06. In order to have an idea about the rate of return to public investments on research in agriculture, macro level data on crop and livestock from Central Statistical Organization (CSO) on the values of output and input was used and the growths in output, input and TFP were estimated for two periods, viz. 1985-86 to 2006-07 and 1990-91 to 2006-07. These estimates are presented in Table 3.19.

**Table 3.19. Total factor productivity and internal rate of return to public sector investments on research in agriculture (crops and livestock) in India: 1985-2006**

| Particulars | Period | |
|---|---|---|
| | 1985-86 to 2006-07 | 1990-91 to 2006-07 |
| Growth in agricultural output, % | 2.92 | 2.80 |
| Growth in inputs used in crop and livestock sectors, % | 2.39 | 2.38 |
| Growth in TFP, % | 0.53 | 0.42 |
| Share of TFP in output growth, % | 17.80 | 14.70 |
| Elasticity of TFP with respect to research investments* | 0.296 | 0.296 |
| Internal rate of return to investments in agricultural research, % | 46.0 | 42.0 |

*From Fan *et al.* (1999)

The growth in agricultural output for the period 1985-2006 was estimated to be 2.92% against the input growth of 2.39%, resulting in 0.53% growth in TFP. The TFP share in output growth was estimated to be 17.8%. The IRR to public research investment in agriculture has been estimated quite high, 46% during this period. Though, there has been a small decline in the output growth and TFP growth as well as in IRR to research since early-1990s, the impact continues to be quite high, IRR being 42% even in the recent period (1990-2006).

## Contribution of Agricultural Research to Crop Output: Quantity and Value

The share of TFP growth in output growth has been estimated in the range of 10.1% for R&M to 58.9% for wheat (vide Table 3.2). The share of agricultural research in TFP growth has been estimated as 55.7% for paddy, 40.1% for wheat, 79.2% for maize, 27.8% for jowar, 74.8 % for bajra, 42.2% for gram, 36.0% for groundnut, 88.6% for R&M and 26.4% for cotton (Table 3.20). These two sets of numbers in shares were multiplied to arrive at the contribution of research to production growth. Based on these estimates it was found that around one-fourth growth in output of wheat and cotton, one-fifth in the case of bajra and around 13% in paddy and maize were due to investments on research in agriculture. In most of the other crops, about one-tenth of output growth was achieved due to public investment on research in agriculture, the lowest being 6.6% in the case of jowar.

These estimates can be readily used to get an idea about the contribution of research to incremental output of food commodities in a given year. The contribution of agricultural research investment to output growth of various crops during the year 2005-06 has been presented in Table 3.20 as an illustration. The growth rate in production of a given crop was used for the period 1975-76 to 2005-06 for assessing the contribution of research to agricultural production. During this period, the output of paddy increased by 2.32% each year in which 0.32 percentage point growth was due to research in agriculture. This implies that 0.32 percentage growth in paddy output during 2005-06 was due to research which amounts to 0.4228 Mt in terms of quantity. Valued even at the minimum support price, this incremental output is worth Rs 241 crore. As mentioned in the Methodology Section, this contribution does not include the research contribution in improving quality which fetches premium price like fine grain or improved basmati varieties. Similarly, the contribution of research in wheat crop during 2005-06 has been estimated to be 0.5896 Mt; it is valued at Rs 636.8 crore. Cotton crop ranked second after wheat in terms of contribution of research; it is valued at Rs 562 crore.

The total contribution of agricultural research in the value of output of the 9 selected crops has been computed as Rs 1552 crore (Table 3.21). These nine crops accounted for about 41% of the value of crop output in 2005-06. If the crops not included in the study also experience a similar growth in TFP and have the same contribution of research to TFP growth as is the average of these nine crops, then the contribution

**Table 3.20. Contribution of agricultural research investment to major crops in India: 2005-06**

**(in per cent)**

| Particulars | Paddy | Wheat | Maize | Jowar | Bajra | Gram | Groundnut | R&M | Cotton |
|---|---|---|---|---|---|---|---|---|---|
| 1. Share of TFP in output growth (%) | 24.5 | 58.9 | 16.5 | 23.7 | 27.6 | 26.1 | 27.1 | 10.1 | 31.6 |
| 2. Share of research in TFP growth (%) | 55.7 | 40.1 | 79.2 | 27.8 | 74.8 | 42.2 | 36.0 | 88.6 | 83.6 |
| 3. Share of research in output growth (%) | 13.6 | 23.6 | 13.1 | 6.6 | 20.6 | 11.0 | 9.8 | 8.9 | 26.4 |
| 4. Crop production growth (%) | 2.321 | 3.507 | 2.897 | 0.33 | 1.738 | 0.608 | 0.842 | 4.492 | 3.109 |
| 5. Contribution of research in production growth (percentage points) | 0.32 | 0.83 | 0.38 | 0.02 | 0.36 | 0.07 | 0.08 | 0.40 | 0.82 |
| 6. Production in 2005-06 (Mt) | 133.47 | 71.27 | 14.67 | 7.21 | 8.01 | 5.8 | 6.54 | 7.72 | 19.19 |
| 7. Contribution of research in production (Mt) | 0.4228 | 0.5896 | 0.0555 | 0.0016 | 0.0287 | 0.0039 | 0.0054 | 0.0310 | 0.1575 |
| 8. Price: 2005-06 (Rs/q) | 570 | 1080 | 525 | 525 | 525 | 1435 | 1520 | 1715 | 3570 |
| 9. Contribution of research to selected crops (in crore Rs) | 241.0 | 636.8 | 29.1 | 0.8 | 15.1 | 5.6 | 8.2 | 53.2 | 562.4 |

**Table 3.21. Contribution of research to crop sector in India: 2005-06**

| Particulars | Value |
|---|---|
| Contribution of research to selected 9 crops (Table 3.20) (in crore Rs) | 1552 |
| Share of the selected crops under study in value of output (%) | 41.4 |
| Research contribution to total crop sectors based on selected crops (in crore Rs) | 3748 |
| Research investment in the year 2005-06 (in crore Rs) | 2814 |
| Returns to research investment (%) | 33.2 |

of research to Indian agriculture comes to be Rs 3748 crore for the crop sector alone (Table 3.21). This contribution is 33% higher than the annual investment in the crop sector research by the public sector in the country. The study has thus clearly shown that the investment on research in agriculture is a highly paying proposition and presents a strong case for additional allocation of research resources for the development of agriculture in the country and attainment of national food and nutritional security.

## Contribution of Agricultural Research to National Self-Sufficiency Attainment

An important contribution of output growth achieved through research in agriculture is the reduction in import dependency for meeting the food requirement of the nation and thus improving national food self-sufficiency. Estimates of contribution of research to output growth prepared in the study were used to quantify the exact contribution of research to attainment of food self-sufficiency of various crops.

Between TE 1975 and TE 2005, the incremental production was of 46 Mt in rice, 44 Mt in wheat, and 8.3 Mt in maize. For other food crops included in the study, the increase in the production volume was relatively small (Table 3.22).

The incremental production was multiplied with the share of research in production growth to arrive at the incremental production due to research. It has been estimated that in the absence of contribution of agricultural research, production in the country in 2005-06 would have been lower by 10.4 Mt in wheat and by 6.3 Mt in rice. The contribution of research to additional production of maize and bajra has been estimated to be 1.09 Mt and 0.64 Mt, respectively. As there has been a decline in the production of jowar over time, it was not considered meaningful to compute contribution of research to jowar production. The cumulative effect of

**Table 3.22. Contribution of research to production and attainment of self-sufficiency in major food commodities in India**

| Particulars | Rice | Wheat | Maize | Jowar | Bajra | Gram | Groundnut | R&M |
|---|---|---|---|---|---|---|---|---|
| 1. Incremental production between TE 1975 and TE 2005 (Mt) | 46.00 | 44.00 | 8.30 | -2.90 | 3.10 | 0.70 | 0.80 | 5.80 |
| 2. Share of research investment in production growth (%) | 13.60 | 23.60 | 13.10 | 6.60 | 20.60 | 11.00 | 9.80 | 8.90 |
| 3. Actual production in 2005-06 (Mt) | 91.79 | 69.35 | 14.71 | 7.24 | 7.68 | 5.60 | 7.99 | 8.13 |
| 4. Incremental production due to research (Mt) | 6.26 | 10.38 | 1.09 | — | 0.64 | 0.08 | 0.08 | 0.52 |
| 5. Likely production without contribution of research investment (Mt) | 85.53 | 60.90 | 13.60 | 7.40 | 7.40 | 5.70 | 6.50 | 7.20 |
| 6. Domestic demand, 2005 (Mt) | 87.30 | 70.70 | 14.15 | 7.24 | 7.68 | 6.36 | 12.05 | 12.28 |
| 7. Self-sufficiency attainment (%) | | | | | | | | |
| Actual 2005-06 | 105.14 | 98.08 | 103.95 | 100.00 | 100.00 | 88.02 | 66.29 | 66.19 |
| Without research contribution | 97.97 | 83.40 | 96.27 | — | 91.68 | 86.81 | 65.64 | 61.99 |
| Contribution of research to self-sufficiency attainment | 7.17 | 14.69 | 7.68 | — | 8.32 | 1.21 | 0.65 | 4.20 |
| 8. Dependence on import without research contribution (Mt) | 1.77 | 9.80 | 0.55 | — | 0.28 | 0.66 | 5.55 | 5.08 |

R&M: Rapeseed & mustard

research in agriculture on output of gram has been estimated as 80 thousand tonnes. In oilseeds, groundnut production would have been lower by 80 thousand tonnes and rapeseed & mustard production would have turned 5.2 lakh tonnes lower without the contribution of agricultural research. Thus, in the absence of research support, the respective output of rice and wheat would have been 85.53 Mt and 60.9 Mt instead of the actual production of 91.79 Mt and 69.35 Mt in the year 2005-06. Similar changes would have happened in other commodities also (Table 3.22).

In all the commodities, the domestic demand in the year 2005-06 was much higher than what would have been the total production in the country without the contribution of research and India would have been far away from attainment of food self-sufficiency. The exact impact of research on self-sufficiency of the selected crops has been presented in Table 3.22. A comparison of domestic demand with domestic production adjusted for trade and change in stock has shown that the domestic production of wheat in the year 2005-06 was enough to meet 98% of the counry's demand. Without contribution of research, self-sufficiency attainment in wheat would have declined to 83.4%. This implies that India would have been forced to import 9.8 Mt of wheat in the absence of research contribution during the past three decades. In rice, India exports about 5% of its domestic production and thus the ratio of production to demand is 105.14%. This ratio declines to 97.9% when incremental output due to research is not counted. Thus, without contribution of research to rice production, India would have been forced to import 1.77 Mt of rice, after wiping out the export of 4 Mt rice. The contribution of research to attainment of self-sufficiency in maize and bajra has been found to be about 8%.

India is not self-sufficient in production of pulses and edible oils and the gap between domestic demand and production is met through import. The contribution of research has not made a significant difference in the level of self-sufficiency in gram and groundnut. In the case of rapeseed & mustard, import dependency of India would have increased from 34% to 38% without the contribution of public sector research to growth of output of rapeseed & mustard.

## Public Investment on Research and Extension in Agriculture

The level of public investment on research and extension in agriculture during the period 1960-61 to 2007-08 has been presented in Appendices 2.1 and 2.2. The series has shown a steady increase in the public investment in agricultural research which was higher than the output growth of agriculture sector till 2002-03. Thereafter, the government spending on agricultural research has stagnated at around 0.6% of GDP in agriculture. The government spending on agricultural extension has been fluctuating, though has moved on a rising trend. The share of agricultural GDP spent on agricultural extension has not shown any specific trend. In recent years, the government has spent about 0.14% of agricultural GDP on extension services.

Looking into the investment in agricultural research series, it was observed that there exists a wide variation in the year-to-year growth in allocation of resources, ranging from 1% to 15%, with average annual growth of 9.1% at nominal price (Table 3.23). Such large fluctuations in resource allocation results in break in research effort, which leads to inefficiency and constraints in attaining desired output. Therefore, there is need to maintain smooth growth in allocation of research resources.

**Table 3.23: Year-wise fluctuation in research resource allocation in India: 2001-2007 (in nominal price)**

| Year | Year-to-year growth in research investment (%) |
|---|---|
| 2001-02 | 1.1 |
| 2002-03 | 10.3 |
| 2003-04 | 4.5 |
| 2004-05 | 8.9 |
| 2005-06 | 15.0 |
| 2006-07 | 13.8 |
| 2007-08 | 8.2 |

In the light of contribution of research in agriculture to self-sufficiency attainment in food, growth of TFP and high payoff to investment in agricultural research and extension, it is imperative to provide adequate funding for research and extension. Considering the importance of public sector research in the growth of agriculture, the Steering Committee on Agriculture for XI Plan has recommended that public funding for agricultural R&E should be raised to 1% of agricultural GDP towards the end of XI Plan (Planning Commission, 2007). This requires a big jump in the allocation of public resources to the agricultural research system of the country.

# 4

# Conclusions and Policy Implications

Large investments were made on research in agriculture in the country with the onset of green revolution during mid-1970s. This helped in the development and promotion of 'HYV seed — fertilizer — irrigation' technology which had a high pay-off and a significant progress was made in food production. Initially, the improved technology was confined to a limited area but after mid-1980s, the country witnessed the spread of improved agricultural technologies to a wider area which continued through the early years of 1990s. However, the productivity growth attained during the decades of 1975-95 could not be sustained during the decade of 1996-05 for a number of important crops. Also, some areas and a few crops did not benefit much from the technological breakthroughs of green revolution period. In recent years, the crop sector has been experiencing diminishing returns to input-use and a significant proportion of the gross cropped area is facing deceleration or stagnation in the TFP growth. In some cases, the TFP has even shown a decline. This has resulted from a number of factors which need to be addressed.

The productivity performance, measured by the growth in TFP, has shown considerable variations across crops and regions. Wheat has enjoyed the highest benefit of technological breakthrough during the past three decades with its TFP growth close to 2%. Rice lags far behind wheat, while maize has witnessed annual TFP growth of around 0.67%. 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 1995-05. In contrast, the TFP growth in bajra, which is entirely a rainfed crop, has been highly impressive. More than half of the total growth in output of wheat and around one-fourth in other cereals have been contributed by the growth in respective TFP.

Except moong, all other major pulse crops have shown either stagnation or decline in the TFP growth, indicating that these crops have not benefited from the technological gains; even the current trends in their production are difficult to sustain. In oilseeds, rapeseed & mustard experienced a strong technological growth during 1975-1985, which halved during 1986-1995 and reached almost zero during 1996-2005. The TFP growth in groundnut has followed improvement in each decade after 1985. The TFP growth for soybean has remained below 1%. Sugarcane production has shown a declining productivity after 1985, indicating that growth in its output is getting increasingly difficult. There was a deceleration in the

TFP growth of cotton and jute after 1985 which continued till 2005. Potato and onion have depicted a complete reversal in TFP trend between 1986-95 and 1996-05. High positive growth in TFP has declined substantially after 1995. Since the entire growth in output of potato and onion has been driven by a higher use of inputs, the economic viability of such a commodity can't be sustained without offering a higher price for it.

Research and technology led output growth has helped in a decline in real cost of production in the range of 1.0-2.3% per annum during the past three decades in the case of cereals. This has helped in keeping the prices of cereals low for consumers and benefiting the producers also through a decline in real cost of production.

As the spread and use of improved technology and other factors associated with growth of crop production were uneven across regions, it was pertinent to examine the changes in TFP and related aspects at the state level. During 1975-2005, the highest growth in TFP in rice has been experienced in Punjab, followed by Andhra Pradesh. The western states of India, including Madhya Pradesh, have benefited a little from the technology and infrastructural related factors in rice output. Even in West Bengal, which is the top ranking state in rice production, TFP has accounted for less than one-fifth of growth in rice output. Except Himachal Pradesh, all wheat-growing states have benefited from the TFP growth with Gujarat at the top. Technology has brought substantial growth and efficiency in maize production in Andhra Pradesh. Jowar production and contribution of technology to it have shown deterioration in most of the selected states, except Maharashtra which stands to benefit from agricultural research in jowar in a big way. Bajra has performed very well in Gujarat, Haryana, Maharashtra and Rajasthan in terms of output growth driven by the technological progress.

The production of pulses has been marred by either declining use of inputs or stagnation/decline in TFP in most of the states. Andhra Pradesh is the only exceptional state which has shown a positive and impressive growth in pulse production as well as in TFP. Other cases of positive growth in output and TFP are: arhar in Karnataka and Maharashtra, and urad in Rajasthan and Uttar Pradesh.

Despite its lacklustre performance at the national level, rapeseed & mustard has performed very well with the support of technology and related factors in Gujarat, Madhya Pradesh and Rajasthan. Similarly, groundnut has shown a significant growth through technology gains in Orissa and moderate growth in Andhra Pradesh and Gujarat. In soybean, though Madhya Pradesh has experienced an unprecedented growth in output, the role of technology in output growth has been mere 4%. The TFP growth has played a significant role in the growth of cotton production during 1975-2005 in Andhra Pradesh and Maharashtra, which has resulted in more than 2% decline in real cost of production of cotton. In sugarcane, output growth in all the selected states has been lower than the growth in use of inputs.

The disaggregate analysis has shown that some crops and states did not witness any significant technological change. There is an urgent need to focus on research and extension for those states which fall under the negative TFP growth or have shown poor performance with stagnating or low TFP growth. If the issue of sustainability in the crop system is not addressed properly, it will adversely affect the long-term growth as well as the national food security and household nutritional security. Further, emphasis on attainment of self-sufficiency in staple food in every state could be a reason for low or stagnant TFP in those crops. Rather there is a need to promote regional specialization based on the comparative advantage of the region.

The public policies such as investment in research, education, extension, infrastructure, and natural resource management have been the major sources of TFP growth. Increase in agricultural investments, especially in agricultural research, is urgently needed to stimulate growth in TFP.

A wide variation exists in allocation of resources across different years, ranging from 1% to 15%. Such large fluctuations in research allocation are not conducive to maintain a consistent research output in the agricultural sector. There is a need to maintain a smooth growth in allocation of research resources.

To attain 4% agricultural growth, as targeted by the Planning Commission, at least one-third of this growth must come through technological innovations and the remaining two-thirds has to be achieved through additional use of agricultural inputs. To meet these targets, investments on agricultural research need to be doubled by 2015 and tripled by 2020 in relation to the investment level of 2002.

Investment in agricultural research has been found to be a highly paying proposition. An additional investment of Re 1 on research has contributed Rs 1.39 to Rs 3.66 in various cereal crops. Crop-specific internal rate of return has been found to vary from around 17% in oilseeds to 55% in arhar.

At the sectoral level (including crop and livestock), the TFP growth has contributed 15% to the total growth in output during 1990-91 to 2006-

07, with an annual growth of 0.42% in TFP. The returns to investment in agricultural research have been estimated as 42%, which is quite a significant contribution to national economy.

The contribution of agricultural research in reducing dependency on import and raising self-sufficiency in food in the country is well known and is cited with pride. In terms of figures, agricultural research carried out during the past three decades has improved self-sufficiency status in wheat by 15% and in rice by 7%. The growth in food production induced by research in India, has not only reduced the import dependency but has also added to export capacity, amounting to 17 million tonnes of cereals. In value terms, it comes to more than four-times the annual investment on agricultural research in the country. It has also reduced pressure on globally traded food commodities. In the absence of contribution of research to Indian agriculture, the global supply of rice and wheat (quantity available for export) would have reduced by about 12%. This could result in a sharp increase in global grain prices, causing adverse effect on food security of a large number of low-income food-deficit countries.

In order to sustain food security and achieve the projected rise in production of food and non-food commodities, essentially through enhancing yield per unit of land, India needs to maintain a steady growth rate in TFP. As TFP increases, the cost of production decreases and consequently, prices fall and stabilize at a lower level. Therefore, both producers and consumers are benefited. The fall in prices of food commodities benefit the urban and rural poor groups more than the upper income groups, because the former spend a much larger proportion of their income on cereals than the latter.

The slowing-down of emphasis on agricultural extension has widened the gap in the adoption and generation of technology. And therefore, there is an immediate need to strengthen the extension services by scaling-up investment levels and improving its quality. The first step in this direction should be an increase in the availability of operating funds for extension activities in agriculture. It will accelerate the TFP growth, improve the sustainability of the crop sector and minimize the yield gap across the regions.

There is a pressing need to focus on acceleration in growth of TFP, whilst conserving natural resources. In the wake of emerging resource constraints, the required growth in yield to meet the target of demand must be achieved from research efforts by developing location-specific and low input-using technologies with emphasis on the region/sub-regions/ districts where the current yields are below the potential national average yield. The states and crops witnessing stagnation or decline in the TFP growth, as identified in the study, must be accorded priority in resource allocation for agricultural research.

Since 2002-03, the government spending on research in agriculture has stagnated at around 0.6% of agricultural GDP. The share of agricultural GDP spent on agricultural extension has not shown any specific trend. In recent years, the government has spent only about 0.14% of agricultural GDP on extension services. Contribution of agricultural research to attainment of self-sufficiency in food and growth in TFP as well as high pay-off to investment in agricultural research and extension are strong justifications for adequate funding for research and extension in agriculture. As recommended by some high level committees, the public funding for research in agriculture should be raised to 1% of agricultural GDP towards the end of XI Plan. It requires a big jump in the allocation of public resources to agricultural research system of the country.

5

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**Appendix 1. Major crops covered under the study for different states of India**

| Crop | State |
|---|---|
| | **Cereals** |
| Paddy | Andhra Pradesh, Assam, Bihar, Haryana, Karnataka, Madhya Pradesh, Orissa, Punjab, Tamil Nadu, Uttar Pradesh, West Bengal |
| Jowar | Andhra Pradesh, Karnataka, Madhya Pradesh, Maharashtra, Rajasthan, Tamil Nadu |
| Bajra | Gujarat, Haryana, Maharashtra, Rajasthan, Tamil Nadu, Uttar Pradesh |
| Maize | Andhra Pradesh, Bihar, Himachal Pradesh, Madhya Pradesh, Rajasthan, Uttar Pradesh |
| Wheat | Bihar, Haryana, Himachal Pradesh, Madhya Pradesh, Punjab, Rajasthan, Uttar Pradesh, West Bengal |
| | **Pulses** |
| Gram | Haryana, Madhya Pradesh, Rajasthan, Uttar Pradesh |
| Moong | Andhra Pradesh, Orissa, Rajasthan |
| Arhar | Gujarat, Karnataka, Madhya Pradesh, Uttar Pradesh |
| Urad | Andhra Pradesh, Madhya Pradesh, Maharashtra, Orissa, Rajasthan, Tamil Nadu, Uttar Pradesh |
| | **Edible oilseeds** |
| Rapeseed & mustard | Assam, Haryana, Punjab, Rajasthan, Uttar Pradesh |
| Groundnut | Andhra Pradesh, Gujarat, Karnataka, Orissa, Tamil Nadu |
| Soybean | Madhya Pradesh |
| | **Fibre crops** |
| Cotton | Andhra Pradesh, Gujarat, Haryana, Karnataka, Madhya Pradesh, Maharashtra, Punjab, Tamil Nadu |
| Jute | Assam, Bihar, Orissa, West Bengal |
| | **Other cash crops** |
| Sugarcane | Andhra Pradesh, Bihar, Haryana, Karnataka, Maharashtra, Tamil Nadu, Uttar Pradesh |

**Appendix 2.1. Government investment on research (including education) in agriculture by sub-sectors in India: 1960-1961 to 2007-08**

**(in million Rs at current prices)**

| Year | Crops | Live-stock | Fisheries | Soil and water conservation | Total | Share of Ag GDP, % |
|---|---|---|---|---|---|---|
| 1960-61 | 96 | 23 | 4 | 3 | 126 | 0.19 |
| 1961-62 | 107 | 28 | 3 | 4 | 142 | 0.20 |
| 1962-63 | 118 | 32 | 4 | 4 | 159 | 0.22 |
| 1963-64 | 135 | 40 | 5 | 5 | 185 | 0.22 |
| 1964-65 | 163 | 48 | 6 | 6 | 223 | 0.22 |
| 1965-66 | 192 | 59 | 7 | 8 | 267 | 0.26 |
| 1966-67 | 224 | 65 | 8 | 9 | 306 | 0.26 |
| 1967-68 | 194 | 72 | 8 | 9 | 284 | 0.19 |
| 1968-69 | 212 | 78 | 9 | 9 | 309 | 0.20 |
| 1969-70 | 338 | 120 | 18 | 11 | 487 | 0.29 |
| 1970-71 | 254 | 94 | 11 | 11 | 370 | 0.21 |
| 1971-72 | 255 | 99 | 12 | 12 | 378 | 0.21 |
| 1972-73 | 316 | 119 | 13 | 16 | 464 | 0.24 |
| 1973-74 | 329 | 122 | 13 | 15 | 480 | 0.19 |
| 1974-75 | 574 | 108 | 16 | 10 | 708 | 0.25 |
| 1975-76 | 722 | 129 | 21 | 13 | 885 | 0.32 |
| 1976-77 | 821 | 144 | 24 | 15 | 1005 | 0.36 |
| 1977-78 | 1003 | 169 | 29 | 19 | 1219 | 0.36 |
| 1978-79 | 1211 | 167 | 22 | 14 | 1413 | 0.41 |
| 1979-80 | 1301 | 184 | 22 | 15 | 1522 | 0.43 |
| 1980-81 | 1372 | 207 | 25 | 18 | 1623 | 0.37 |
| 1981-82 | 1594 | 231 | 30 | 20 | 1875 | 0.38 |
| 1982-83 | 1777 | 247 | 30 | 20 | 2074 | 0.39 |
| 1983-84 | 2077 | 293 | 39 | 24 | 2432 | 0.38 |
| 1984-85 | 2404 | 348 | 48 | 30 | 2830 | 0.41 |
| 1985-86 | 2697 | 408 | 57 | 34 | 3196 | 0.43 |
| 1986-87 | 2760 | 749 | 84 | 53 | 3646 | 0.46 |
| 1987-88 | 3336 | 505 | 65 | 35 | 3941 | 0.44 |
| 1988-89 | 4052 | 639 | 75 | 58 | 4824 | 0.44 |
| 1989-90 | 4910 | 764 | 87 | 59 | 5820 | 0.48 |
| 1990-91 | 5505 | 1343 | 135 | 141 | 7125 | 0.50 |
| 1991-92 | 5956 | 1444 | 160 | 145 | 7705 | 0.46 |
| 1992-93 | 6313 | 1480 | 173 | 150 | 8116 | 0.43 |
| 1993-94 | 7422 | 1788 | 198 | 179 | 9586 | 0.44 |
| 1994-95 | 8474 | 2012 | 223 | 202 | 10911 | 0.43 |
| 1995-96 | 9895 | 1642 | 550 | 159 | 12245 | 0.45 |
| 1996-97 | 11098 | 1566 | 526 | 152 | 13342 | 0.40 |
| 1997-98 | 12750 | 2031 | 614 | 155 | 15549 | 0.44 |
| 1998-99 | 16229 | 2434 | 724 | 161 | 19548 | 0.48 |
| 1999-00 | 20452 | 2630 | 767 | 153 | 24002 | 0.56 |
| 2000-01 | 21214 | 2836 | 859 | 179 | 25088 | 0.58 |
| 2001-02 | 21065 | 3071 | 1031 | 205 | 25372 | 0.54 |
| 2002-03 | 20815 | 3854 | 1374 | 1952 | 27996 | 0.62 |
| 2003-04 | 21667 | 4083 | 1371 | 2155 | 29275 | 0.57 |
| 2004-05 | 24196 | 3857 | 1605 | 2237 | 31895 | 0.60 |
| 2005-06 | 28138 | 4216 | 1939 | 2397 | 36689 | 0.62 |
| 2006-07 | 32768 | 4635 | 2125 | 2221 | 41749 | 0.62 |
| 2007-08 | 33160 | 5416 | 2021 | 2488 | 43085 | 0.57 |

**Appendix 2.2. Government investment in agricultural extension by sub-sectors in India: 1960-61 to 2007-08**

**(in million Rs at current prices)**

| Year | Crops | Live-stock | Fisheries | Soil and water conservation | Total | Share of Ag GDP, % |
|---|---|---|---|---|---|---|
| 1960-61 | 55 | 3 | 3 | 2 | 63 | 0.09 |
| 1961-62 | 50 | 4 | 4 | 2 | 61 | 0.09 |
| 1962-63 | 44 | 4 | 4 | 2 | 55 | 0.08 |
| 1963-64 | 64 | 6 | 5 | 2 | 78 | 0.09 |
| 1964-65 | 76 | 8 | 7 | 3 | 94 | 0.09 |
| 1965-66 | 108 | 12 | 8 | 4 | 133 | 0.13 |
| 1966-67 | 242 | 18 | 13 | 7 | 280 | 0.23 |
| 1967-68 | 176 | 14 | 12 | 5 | 206 | 0.14 |
| 1968-69 | 177 | 13 | 12 | 6 | 207 | 0.13 |
| 1969-70 | 151 | 11 | 10 | 5 | 177 | 0.10 |
| 1970-71 | 156 | 12 | 10 | 5 | 184 | 0.11 |
| 1971-72 | 207 | 8 | 8 | 4 | 227 | 0.13 |
| 1972-73 | 235 | 11 | 11 | 8 | 265 | 0.14 |
| 1973-74 | 285 | 17 | 20 | 11 | 333 | 0.13 |
| 1974-75 | 115 | 10 | 6 | 5 | 137 | 0.05 |
| 1975-76 | 155 | 12 | 8 | 6 | 181 | 0.07 |
| 1976-77 | 152 | 13 | 9 | 6 | 180 | 0.06 |
| 1977-78 | 166 | 15 | 10 | 7 | 198 | 0.06 |
| 1978-79 | 227 | 19 | 11 | 8 | 264 | 0.08 |
| 1979-80 | 312 | 22 | 15 | 9 | 358 | 0.10 |
| 1980-81 | 467 | 26 | 17 | 10 | 520 | 0.12 |
| 1981-82 | 374 | 29 | 18 | 12 | 433 | 0.09 |
| 1982-83 | 516 | 31 | 24 | 17 | 588 | 0.11 |
| 1983-84 | 706 | 65 | 32 | 25 | 828 | 0.13 |
| 1984-85 | 761 | 73 | 31 | 27 | 892 | 0.13 |
| 1985-86 | 989 | 97 | 45 | 33 | 1165 | 0.16 |
| 1986-87 | 1147 | 66 | 48 | 37 | 1298 | 0.16 |
| 1987-88 | 1136 | 111 | 52 | 29 | 1327 | 0.15 |
| 1988-89 | 1359 | 64 | 63 | 39 | 1525 | 0.14 |
| 1989-90 | 1837 | 146 | 70 | 52 | 2105 | 0.17 |
| 1990-91 | 2009 | 146 | 68 | 57 | 2280 | 0.16 |
| 1991-92 | 2201 | 145 | 75 | 64 | 2486 | 0.15 |
| 1992-93 | 2352 | 201 | 80 | 68 | 2701 | 0.14 |
| 1993-94 | 2476 | 172 | 88 | 74 | 2810 | 0.13 |
| 1994-95 | 2905 | 193 | 94 | 85 | 3277 | 0.13 |
| 1995-96 | 3490 | 149 | 166 | 221 | 4026 | 0.15 |
| 1996-97 | 3771 | 113 | 178 | 168 | 4231 | 0.13 |
| 1997-98 | 4479 | 134 | 181 | 150 | 4945 | 0.14 |
| 1998-99 | 5937 | 127 | 212 | 169 | 6445 | 0.16 |
| 1999-00 | 5591 | 169 | 213 | 194 | 6168 | 0.14 |
| 2000-01 | 4417 | 154 | 216 | 166 | 4953 | 0.12 |
| 2001-02 | 4547 | 298 | 204 | 176 | 5226 | 0.11 |
| 2002-03 | 4320 | 310 | 303 | 175 | 5108 | 0.11 |
| 2003-04 | 4557 | 317 | 276 | 174 | 5324 | 0.10 |
| 2004-05 | 4948 | 402 | 205 | 172 | 5727 | 0.11 |
| 2005-06 | 6742 | 541 | 225 | 190 | 7699 | 0.13 |
| 2006-07 | 8503 | 636 | 269 | 177 | 9585 | 0.14 |
| 2007-08 | 9459 | 698 | 320 | 178 | 10656 | 0.14 |

**Appendix 2.3. Research stock for different sub-sectors of agriculture in India: 1966-67 to 2007-08**

**(in million Rs at current prices)**

| Year | Crops | Live-stock | Fisheries | Soil and water conservation | Total |
|---|---|---|---|---|---|
| 1966-67 | 339 | 91 | 12 | 11 | 453 |
| 1967-68 | 386 | 109 | 13 | 13 | 521 |
| 1968-69 | 445 | 130 | 16 | 14 | 605 |
| 1969-70 | 509 | 155 | 19 | 15 | 697 |
| 1970-71 | 571 | 180 | 22 | 17 | 789 |
| 1971-72 | 640 | 211 | 26 | 18 | 894 |
| 1972-73 | 692 | 237 | 30 | 19 | 978 |
| 1973-74 | 719 | 264 | 33 | 23 | 1040 |
| 1974-75 | 800 | 294 | 38 | 24 | 1155 |
| 1975-76 | 886 | 326 | 42 | 19 | 1274 |
| 1976-77 | 894 | 315 | 37 | 20 | 1266 |
| 1977-78 | 1079 | 337 | 41 | 22 | 1479 |
| 1978-79 | 1377 | 362 | 47 | 27 | 1813 |
| 1979-80 | 1750 | 377 | 54 | 24 | 2206 |
| 1980-81 | 2287 | 398 | 64 | 24 | 2773 |
| 1981-82 | 2725 | 449 | 71 | 27 | 3272 |
| 1982-83 | 3145 | 495 | 74 | 30 | 3743 |
| 1983-84 | 3620 | 542 | 76 | 31 | 4268 |
| 1984-85 | 4068 | 580 | 73 | 36 | 4757 |
| 1985-86 | 4482 | 646 | 80 | 44 | 5252 |
| 1986-87 | 5025 | 727 | 93 | 51 | 5896 |
| 1987-88 | 5763 | 825 | 108 | 73 | 6769 |
| 1988-89 | 6511 | 1003 | 130 | 63 | 7707 |
| 1989-90 | 7389 | 1217 | 157 | 82 | 8845 |
| 1990-91 | 8362 | 1454 | 185 | 89 | 10089 |
| 1991-92 | 9509 | 1719 | 210 | 177 | 11615 |
| 1992-93 | 10924 | 2111 | 242 | 214 | 13492 |
| 1993-94 | 12917 | 2301 | 263 | 236 | 15717 |
| 1994-95 | 14928 | 2930 | 324 | 268 | 18450 |
| 1995-96 | 16898 | 3654 | 400 | 304 | 21255 |
| 1996-97 | 18721 | 4503 | 491 | 275 | 23991 |
| 1997-98 | 20828 | 4833 | 616 | 256 | 26534 |
| 1998-99 | 23513 | 5087 | 790 | 247 | 29637 |
| 1999-00 | 27127 | 5415 | 1039 | 253 | 33834 |
| 2000-01 | 31394 | 5564 | 1368 | 248 | 38574 |
| 2001-02 | 37005 | 5613 | 1781 | 272 | 44672 |
| 2002-03 | 43459 | 6270 | 1930 | 307 | 51966 |
| 2003-04 | 50703 | 7305 | 2203 | 2070 | 62280 |
| 2004-05 | 57908 | 8239 | 2540 | 2977 | 71664 |
| 2005-06 | 62722 | 9100 | 2896 | 3489 | 78208 |
| 2006-07 | 64061 | 10010 | 3377 | 3723 | 81171 |
| 2007-08 | 66023 | 10990 | 3982 | 3627 | 84623 |

**Appendix 2.4. Extension stock for different sub-sectors of agriculture in India: 1963-64 to 2007-08**

**(in million Rs at current prices)**

| Year | Crops | Live-stock | Fisheries | Soil and water conservation | Total |
|---|---|---|---|---|---|
| 1963-64 | 75 | 7 | 7 | 3 | 91 |
| 1964-65 | 92 | 9 | 8 | 3 | 112 |
| 1965-66 | 110 | 11 | 10 | 5 | 136 |
| 1966-67 | 151 | 16 | 12 | 6 | 186 |
| 1967-78 | 301 | 24 | 18 | 9 | 351 |
| 1968-69 | 294 | 23 | 19 | 9 | 345 |
| 1969-70 | 295 | 22 | 19 | 9 | 346 |
| 1970-71 | 256 | 19 | 17 | 8 | 301 |
| 1971-72 | 252 | 20 | 16 | 8 | 296 |
| 1972-73 | 300 | 15 | 14 | 7 | 336 |
| 1973-74 | 349 | 17 | 16 | 11 | 393 |
| 1974-75 | 420 | 24 | 26 | 15 | 484 |
| 1975-76 | 276 | 20 | 16 | 11 | 323 |
| 1976-77 | 257 | 20 | 15 | 10 | 302 |
| 1977-78 | 237 | 20 | 13 | 9 | 279 |
| 1978-79 | 257 | 23 | 15 | 11 | 306 |
| 1979-80 | 323 | 28 | 17 | 12 | 379 |
| 1980-81 | 435 | 33 | 22 | 13 | 504 |
| 1981-82 | 637 | 39 | 25 | 15 | 716 |
| 1982-83 | 623 | 44 | 28 | 18 | 712 |
| 1983-84 | 759 | 48 | 34 | 24 | 865 |
| 1984-85 | 987 | 83 | 45 | 34 | 1149 |
| 1985-86 | 1147 | 105 | 49 | 40 | 1341 |
| 1986-87 | 1435 | 139 | 64 | 49 | 1687 |
| 1987-88 | 1695 | 119 | 72 | 56 | 1942 |
| 1988-89 | 1793 | 156 | 80 | 51 | 2079 |
| 1989-90 | 2043 | 121 | 93 | 58 | 2315 |
| 1990 -91 | 2608 | 194 | 105 | 73 | 2980 |
| 1991-92 | 3016 | 217 | 109 | 85 | 3427 |
| 1992-93 | 3372 | 233 | 117 | 97 | 3819 |
| 1993-94 | 3634 | 288 | 124 | 105 | 4151 |
| 1994-95 | 3857 | 282 | 135 | 114 | 4387 |
| 1995-96 | 4366 | 302 | 145 | 121 | 4664 |
| 1996-97 | 5147 | 261 | 221 | 128 | 4941 |
| 1997-98 | 5748 | 212 | 263 | 217 | 6104 |
| 1998-99 | 6686 | 209 | 286 | 235 | 7293 |
| 1999-00 | 8483 | 203 | 320 | 263 | 9269 |
| 2000-01 | 8862 | 247 | 334 | 292 | 9734 |
| 2001-02 | 7841 | 247 | 344 | 278 | 8709 |
| 2002-03 | 7432 | 394 | 333 | 282 | 8440 |
| 2003-04 | 7022 | 460 | 428 | 278 | 8189 |
| 2004-05 | 7194 | 500 | 438 | 280 | 8412 |
| 2005-06 | 7635 | 590 | 376 | 277 | 8878 |
| 2006-07 | 9633 | 765 | 362 | 294 | 11054 |
| 2007-08 | 12189 | 933 | 400 | 288 | 13810 |

**Appendix 3. Annual growth rates in input use, output and TFP for major crops in India: TE 2005**

**(in per cent)**

| Crop | Period | Input growth | Output growth | TFP growth |
|---|---|---|---|---|
| Rice | 1975-85 | 3.38 | 4.28 | 0.90 |
| | 1986-95 | 2.42 | 3.16 | 0.74 |
| | 1996-05 | 0.52 | 0.93 | 0.40 |
| | 1975-05 | 2.05 | 2.72 | 0.67 |
| Wheat | 1975-85 | 4.30 | 5.90 | 1.60 |
| | 1986-95 | 1.16 | 3.68 | 2.51 |
| | 1996-05 | -0.86 | 0.74 | 1.61 |
| | 1975-05 | 1.34 | 3.26 | 1.92 |
| Maize | 1975-85 | 16.58 | 18.58 | 2.00 |
| | 1986-95 | 5.08 | 5.75 | 0.67 |
| | 1996-05 | 3.66 | 5.31 | 1.64 |
| | 1975-05 | 7.03 | 8.42 | 1.39 |
| Jowar | 1975-85 | 5.86 | 7.00 | 1.15 |
| | 1986-95 | -1.33 | -0.58 | 0.74 |
| | 1996-05 | -0.46 | -0.89 | -0.42 |
| | 1975-05 | 2.02 | 2.65 | 0.63 |
| Bajra | 1975-85 | 3.35 | 4.57 | 1.22 |
| | 1986-95 | 3.80 | 4.19 | 0.39 |
| | 1996-05 | 1.18 | 2.68 | 1.50 |
| | 1975-05 | 2.74 | 3.78 | 1.04 |
| Barley | 1975-85 | 8.76 | 11.44 | 2.68 |
| | 1986-95 | 1.01 | 1.45 | 0.44 |
| | 1996-05 | -2.05 | -1.44 | 0.61 |
| | 1975-05 | 3.32 | 4.70 | 1.38 |
| Gram | 1975-85 | 4.55 | 4.61 | 0.06 |
| | 1986-95 | 1.50 | 1.59 | 0.09 |
| | 1996-05 | 0.14 | 0.48 | 0.34 |
| | 1975-05 | 2.06 | 2.23 | 0.16 |
| Moong | 1986-95 | 1.80 | 1.21 | -0.59 |
| | 1996-05 | 7.88 | 9.58 | 1.70 |
| | 1975-05 | 4.76 | 5.29 | 0.53 |

*Contd.*

**Appendix 3** ***Contd.....***

| Crop | Period | Input growth | Output growth | TFP growth |
|---|---|---|---|---|
| Arhar | 1986-95 | 0.41 | 0.62 | 0.21 |
| | 1996-05 | -0.27 | -0.82 | -0.54 |
| | 1975-05 | 0.21 | -0.48 | -0.69 |
| Urad | 1986-95 | 4.49 | 4.27 | -0.22 |
| | 1996-05 | 1.32 | 0.58 | -0.73 |
| | 1975-05 | 2.93 | 2.46 | -0.47 |
| Soybean | 1986-95 | 17.26 | 18.09 | 0.83 |
| | 1996-05 | 8.85 | 9.48 | 0.63 |
| | 1975-05 | 12.24 | 12.96 | 0.71 |
| Groundnut | 1975-85 | 2.07 | 2.56 | 0.49 |
| | 1986-95 | -0.73 | -0.18 | 0.55 |
| | 1996-05 | -1.72 | -0.42 | 1.30 |
| | 1975-05 | 0.01 | 0.78 | 0.77 |
| Rapeseed & mustard | 1975-85 | 9.12 | 11.00 | 1.88 |
| | 1986-95 | 8.51 | 9.26 | 0.74 |
| | 1996-05 | 4.38 | 4.46 | 0.08 |
| | 1975-05 | 6.99 | 7.78 | 0.79 |
| Sugarcane | 1975-85 | 5.02 | 6.40 | 1.38 |
| | 1986-95 | 4.91 | 4.60 | -0.32 |
| | 1996-05 | 3.19 | 1.53 | -1.65 |
| | 1975-05 | 4.23 | 3.82 | -0.41 |
| Cotton | 1975-85 | 5.26 | 8.10 | 2.84 |
| | 1986-95 | 3.36 | 4.28 | 0.92 |
| | 1996-05 | 0.94 | 1.74 | 0.80 |
| | 1975-05 | 3.05 | 4.46 | 1.41 |
| Jute | 1975-85 | 1.40 | 3.28 | 1.88 |
| | 1986-95 | -1.18 | 0.41 | 1.59 |
| | 1996-05 | 0.10 | 0.35 | 0.25 |
| | 1975-05 | 0.08 | 1.36 | 1.28 |
| Onion | 1986-95 | 0.89 | 3.26 | 2.37 |
| | 1996-05 | 15.44 | 13.82 | -1.62 |
| | 1975-05 | 11.33 | 10.84 | -0.49 |
| Potato | 1986-95 | 2.45 | 3.65 | 1.20 |
| | 1996-05 | 16.17 | 14.89 | -1.28 |
| | 1975-05 | 13.32 | 12.56 | -0.76 |

**Appendix 4. The share of crop area and production by states in India: TE 2005**

**(in per cent)**

| State | Area share | Production share |
|---|---|---|
| | **Paddy** | |
| West Bengal | 13.2 | 15.8 |
| Andhra Pradesh | 9.1 | 12.8 |
| Uttar Pradesh | 12.8 | 12.1 |
| Punjab | 6.1 | 11.1 |
| Orissa | 10.3 | 7.5 |
| Karnataka | 3.4 | 6.3 |
| Tamil Nadu | 4.7 | 5.7 |
| Assam | 5.5 | 3.9 |
| Bihar | 7.4 | 3.8 |
| Haryana | 2.4 | 3.5 |
| Other states | 25.0 | 17.6 |
| | **Wheat** | |
| Uttar Pradesh | 34.6 | 34.7 |
| Punjab | 13.1 | 20.9 |
| Haryana | 8.7 | 12.8 |
| Madhya Pradesh | 13.9 | 8.6 |
| Rajasthan | 8.0 | 8.5 |
| Bihar | 7.6 | 4.7 |
| Gujarat | 3.5 | 3.6 |
| Maharashtra | 3.5 | 1.9 |
| West Bengal | 1.4 | 1.1 |
| Himachal Pradesh | 1.4 | 1.0 |
| Other states | 4.4 | 2.4 |
| | **Maize** | |
| Andhra Pradesh | 10.0 | 21.0 |
| Karnataka | 12.3 | 18.5 |
| Bihar | 8.6 | 9.3 |
| Madhya Pradesh | 11.4 | 8.5 |
| Rajasthan | 13.2 | 7.5 |
| Uttar Pradesh | 10.7 | 7.2 |
| Maharashtra | 6.2 | 6.8 |
| Gujarat | 6.6 | 3.8 |
| Himachal Pradesh | 3.9 | 3.7 |
| Other states | 17.1 | 23.8 |

*Contd.*

**Appendix 4** ***Contd.....***

| State | Area share | Production share |
|---|---|---|
| | **Jowar** | |
| Maharashtra | 54.7 | 51.2 |
| Andhra Pradesh | 5.1 | 7.7 |
| Uttar Pradesh | 2.6 | 3.2 |
| Tamil Nadu | 3.6 | 3.0 |
| Rajasthan | 6.8 | 2.2 |
| Other states | 2.9 | 2.6 |
| | **Bajra** | |
| Rajasthan | 51.8 | 35.9 |
| Uttar Pradesh | 9.1 | 16.2 |
| Gujarat | 9.6 | 14.0 |
| Maharashtra | 15.0 | 13.4 |
| Haryana | 6.2 | 8.8 |
| Madhya Pradesh | 4.5 | 5.5 |
| Karnataka | 1.9 | 3.5 |
| Tamil Nadu | 0.9 | 1.2 |
| Other states | 1.2 | 1.4 |
| | **Gram** | |
| Madhya Pradesh | 37.0 | 42.3 |
| Maharashtra | 14.7 | 12.6 |
| Uttar Pradesh | 10.7 | 11.8 |
| Rajasthan | 15.6 | 8.6 |
| Haryana | 1.9 | 1.3 |
| Bihar | 0.9 | 1.0 |
| Other states | 19.2 | 22.4 |
| | **Arhar** | |
| Maharashtra | 30.7 | 28.9 |
| Karnataka | 16.8 | 16.0 |
| Uttar Pradesh | 10.7 | 13.8 |
| Andhra Pradesh | 13.8 | 11.0 |
| Gujarat | 7.1 | 10.2 |
| Madhya Pradesh | 9.0 | 8.7 |
| Orissa | 3.7 | 3.6 |
| Tamil Nadu | 1.1 | 0.7 |
| Other states | 7.2 | 7.1 |

*Contd.*

**Appendix 4** ***Contd.....***

| State | Area share | Production share |
|---|---|---|
| | **Moong** | |
| Maharashtra | 21.5 | 25.5 |
| Rajasthan | 32.2 | 17.9 |
| Andhra Pradesh | 10.2 | 16.9 |
| Bihar | 7.0 | 14.0 |
| Karnataka | 15.8 | 12.7 |
| Orissa | 5.3 | 6.2 |
| Madhya Pradesh | 3.1 | 3.6 |
| Other states | 4.5 | 3.0 |
| | **Urad** | |
| Andhra Pradesh | 14.9 | 22.7 |
| Uttar Pradesh | 21.5 | 21.7 |
| Maharashtra | 20.4 | 20.7 |
| Madhya Pradesh | 19.4 | 15.9 |
| Tamil Nadu | 7.3 | 6.3 |
| Gujarat | 4.2 | 4.1 |
| Rajasthan | 6.1 | 4.0 |
| Orissa | 5.6 | 3.6 |
| Other states | 1.0 | 1.0 |
| | **Rapeseed and mustard** | |
| Rajasthan | 50.4 | 54.3 |
| Uttar Pradesh | 11.1 | 11.3 |
| Madhya Pradesh | 11.9 | 10.7 |
| Haryana | 9.7 | 9.7 |
| Gujarat | 4.6 | 5.6 |
| West Bengal | 5.8 | 4.7 |
| Assam | 2.9 | 1.2 |
| Bihar | 1.1 | .9 |
| Punjab | .7 | .7 |
| Other states | 2.0 | 1.0 |
| | **Groundnut** | |
| Gujarat | 29.0 | 42.4 |
| Andhra Pradesh | 27.9 | 17.1 |
| Tamil Nadu | 9.2 | 13.7 |
| Karnataka | 15.4 | 8.4 |
| Rajasthan | 4.7 | 6.1 |

*Contd.*

**Appendix 4 *Contd.....***

| State | Area share | Production share |
|---|---|---|
| Maharashtra | 6.4 | 5.1 |
| Madhya Pradesh | 3.1 | 2.9 |
| Orissa | 1.3 | 1.3 |
| Other states | 3.0 | 3.0 |
| | **Soybean** | |
| Madhya Pradesh | 55.2 | 54.4 |
| Maharashtra | 30.5 | 30.5 |
| Rajasthan | 9.7 | 10.3 |
| Other states | 4.7 | 4.7 |
| | **Sugarcane** | |
| Uttar Pradesh | 51.3 | 44.6 |
| Maharashtra | 11.9 | 13.8 |
| Tamil Nadu | 8.0 | 12.5 |
| Karnataka | 5.2 | 6.5 |
| Andhra Pradesh | 5.5 | 6.3 |
| Gujarat | 4.7 | 5.2 |
| Haryana | 3.0 | 2.9 |
| Punjab | 2.0 | 1.7 |
| Bihar | 2.4 | 1.5 |
| Other states | 6.0 | 4.9 |
| | **Cotton** | |
| Gujarat | 22.0 | 36.6 |
| Maharashtra | 33.1 | 17.1 |
| Punjab | 6.4 | 12.9 |
| Andhra Pradesh | 11.9 | 11.4 |
| Haryana | 6.7 | 8.1 |
| Rajasthan | 5.4 | 4.8 |
| Madhya Pradesh | 7.1 | 4.0 |
| Karnataka | 4.8 | 3.0 |
| Tamil Nadu | 1.6 | 1.2 |
| Other states | 0.9 | 0.9 |
| | **Jute** | |
| West Bengal | 73.6 | 80.1 |
| Bihar | 17.5 | 13.0 |
| Assam | 7.6 | 5.8 |
| Orissa | .4 | .4 |
| Other states | 1.0 | .6 |

**Appendix 5. Determinants of TFP for different crops in India: 1975-2005**

**Rice**

**(Dependent variable: TFP index of rice at state level)**

| Variable | Regression coefficient | Standard error | 't' statistics | Level of significance |
|---|---|---|---|---|
| | | **Model 1** | | |
| Constant | 3.95746 | 0.40273 | 9.83 | |
| RES_STOK | 0.04538 | 0.01556 | 2.92 | 0.004 |
| EXT_STOK | -0.00516 | 0.00848 | -0.61 | 0.543 |
| LIT_R | -0.10276 | 0.07285 | -1.41 | 0.159 |
| NARI | 0.12581 | 0.04240 | 2.97 | 0.003 |
| INF | 0.06385 | 0.03756 | 1.70 | 0.090 |
| MP | 0.21219 | 0.02966 | 7.16 | 0.000 |
| BH | 0.16402 | 0.02862 | 5.73 | 0.000 |
| AS | 0.17213 | 0.03143 | 5.48 | 0.000 |
| KN | 0.10447 | 0.02948 | 3.54 | 0.000 |
| TN | 0.09283 | 0.03178 | 2.92 | 0.004 |
| HY | 0.02870 | 0.03314 | 0.87 | 0.387 |
| WB | -0.07251 | 0.02826 | -2.57 | 0.011 |
| AP | -0.18424 | 0.03157 | -5.84 | 0.000 |
| PB | -0.31339 | 0.02898 | -10.81 | 0.000 |
| Adjusted R square | 0.650 | | | |
| | | **Model 2** | | |
| Constant | 1.30481 | 0.76415 | 1.71 | |
| RES_STOK | 0.04769 | 0.01667 | 2.86 | 0.005 |
| EXT_STOK | -0.00273 | 0.00825 | -0.33 | 0.741 |
| LIT_R | -0.09380 | 0.07382 | -1.27 | 0.205 |
| CI | 0.55051 | 0.14877 | 3.70 | 0.000 |
| NPRATIO | 0.08467 | 0.02352 | 3.60 | 0.000 |
| IRR_GW | 0.03933 | 0.03475 | 1.13 | 0.259 |
| Road | 0.12472 | 0.03768 | 3.31 | 0.001 |
| ELECT_AG | -0.03856 | 0.01146 | -3.36 | 0.001 |
| MP | 0.17070 | 0.03060 | 5.58 | 0.000 |
| AS | 0.16379 | 0.03902 | 4.20 | 0.000 |
| BH | 0.08423 | 0.03326 | 2.53 | 0.012 |
| KN | 0.06775 | 0.03010 | 2.25 | 0.025 |
| HY | 0.03151 | 0.03314 | 0.95 | 0.342 |
| TN | 0.00895 | 0.03562 | 0.25 | 0.802 |
| WB | -0.05136 | 0.03038 | -1.69 | 0.092 |
| AP | -0.22965 | 0.03147 | -7.30 | 0.000 |
| PB | -0.31434 | 0.02856 | -11.01 | 0.000 |
| Adjusted R Square | 0.672 | | | |

*Notes:* RES_STOK: Research investment stock, EXT_STOK: Extension investment stock index, LIT_R: % of literate rural population, NARI: Natural agricultural resources index, INF: Infrastructural management index, CI: cropping intensity in %, NPRATIO: $N_2O$ and $P_2O_5$ fertilizer ratio, IRR_GW: Groundwater irrigation index, Road: Road density index, ELECT_AG: Electricity consumption for agricultural index. All variables are specified in logarithms, except those variables which are defined in percentage terms. State dummy variables have been included in both the models.

**Appendix 5** ***Contd.....***

**Wheat**

**(Dependent variable: TFP index of wheat at state level)**

| Variable | Regression coefficient | Standard error | 't' statistics | Level of significance |
|---|---|---|---|---|
| | | **Model 1** | | |
| Constant | 4.45257 | 0.52579 | 8.47 | |
| RES_STOK | 0.05133 | 0.0181 | 2.84 | 0.005 |
| EXT_STOK | -0.01611 | 8.90E-03 | -1.81 | 0.072 |
| LIT_R | 0.03081 | 0.09828 | 0.31 | 0.754 |
| NARI | -0.04885 | 0.08773 | -0.56 | 0.578 |
| INF | -0.00441 | 0.07488 | -0.06 | 0.953 |
| BH | 0.13803 | 0.0547 | 2.52 | 0.012 |
| HP | 0.12881 | 0.05199 | 2.48 | 0.014 |
| HY | 0.11891 | 0.05304 | 2.24 | 0.026 |
| WB | 0.10081 | 0.05265 | 1.91 | 0.057 |
| PB | 0.07511 | 0.04908 | 1.53 | 0.127 |
| RJ | 0.04428 | 0.06877 | 0.64 | 0.520 |
| UP | 0.02835 | 0.06013 | 0.47 | 0.638 |
| MP | 0.02283 | 0.05608 | 0.41 | 0.684 |
| Adjusted R square | 0.227 | | | |
| | | **Model 2** | | |
| Constant | 0.51473 | 1.31998 | 0.39 | |
| RES_STOK | 0.0514 | 0.02232 | 2.09 | 0.4595 |
| EXT_STOK | -0.01492 | 8.49E-03 | -1.76 | 0.0802 |
| LIT_R | 0.01335 | 0.09288 | 0.14 | 0.8859 |
| CI | 0.71141 | 0.26089 | 2.73 | 0.0069 |
| NPRATIO | -0.03378 | 0.04032 | -0.84 | 0.4031 |
| IRR_GW | 0.01547 | 0.08502 | 0.18 | 0.8557 |
| Road | 0.20496 | 0.07598 | 2.70 | 0.0075 |
| ELECT_AG | -0.03813 | 0.02105 | -1.81 | 0.0713 |
| WB | 0.16840 | 0.06250 | 2.69 | 0.0076 |
| HY | 0.08640 | 0.05496 | 1.57 | 0.1173 |
| HP | 0.06363 | 0.05408 | 1.18 | 0.2405 |
| PB | 0.04808 | 0.04989 | 0.96 | 0.3362 |
| UP | 0.01679 | 0.05937 | 0.28 | 0.7776 |
| BH | 0.01682 | 0.06263 | 0.27 | 0.7885 |
| RJ | 0.01348 | 0.06858 | 0.20 | 0.8444 |
| MP | -0.04615 | 0.06071 | -0.76 | 0.4479 |
| Adjusted R square | 0.254 | | | |

*Notes:* RES_STOK: Research investment stock, EXT_STOK: Extension investment stock index, LIT_R: % of literate rural population, NARI: Natural agricultural resources index, INF: Infrastructural management index, CI: cropping intensity in %, NPRATIO: $N_2O$ and $P_2O_5$ fertilizer ratio, IRR_GW: Groundwater irrigation index, Road: Road density index, ELECT_AG: Electricity consumption for agricultural index. All variables are specified in logarithms, except those variables which are defined in percentage terms. State dummy variables have been included in both the models.

**Appendix 5** ***Contd.....***

**Maize**

**(Dependent variable: TFP index of maize at state level)**

| Variable | Regression coefficient | Standard error | 't' statistics | Level of significance |
|---|---|---|---|---|
| | | **Model 1** | | |
| Constant | 3.4025 | 0.99998 | 3.40 | |
| RES_STOK | 0.07283 | 0.03924 | 1.86 | 0.0812 |
| EXT_STOK | 0.03386 | 0.02406 | 1.41 | 0.1616 |
| LIT_R | 0.13091 | 0.21196 | 0.62 | 0.5379 |
| NARI | 0.30631 | 0.12654 | 2.42 | 0.0168 |
| INF | -0.29584 | 0.10758 | -2.75 | 0.0068 |
| RJ | 0.62411 | 0.05879 | 10.62 | 0 |
| HP | 0.62278 | 0.07232 | 8.61 | 0 |
| MP | 0.30902 | 0.05646 | 5.47 | 0 |
| AP | 0.17388 | 0.07212 | 2.41 | 0.0172 |
| BH | -0.05405 | 0.05659 | -0.96 | 0.3412 |
| Adjusted R square | 0.788 | | | |
| | | **Model 2** | | |
| Constant | 1.79526 | 3.06893 | 0.58 | |
| RES_STOK | 0.07438 | 0.03879 | 1.92 | 0.0723 |
| EXT_STOK | 0.01216 | 0.02614 | 0.47 | 0.6426 |
| LIT_R | 0.02014 | 0.21453 | 0.09 | 0.9253 |
| CI | 0.16448 | 0.68280 | 0.24 | 0.81 |
| NPRATIO | 0.14958 | 0.05597 | 2.67 | 0.0085 |
| IRR_GW | 0.15123 | 0.11913 | 1.27 | 0.2065 |
| Road | 0.11480 | 0.12779 | 0.90 | 0.3707 |
| ELECT_AG | -0.09100 | 0.03434 | -2.65 | 0.009 |
| RJ | 0.61228 | 0.06507 | 9.41 | 0 |
| HP | 0.59003 | 0.07573 | 7.79 | 0 |
| MP | 0.26197 | 0.06802 | 3.85 | 0.0002 |
| AP | 0.17040 | 0.07384 | 2.31 | 0.0226 |
| BH | -0.12495 | 0.07293 | -1.71 | 0.089 |
| Adjusted R square | 0.790 | | | |

*Notes:* RES_STOK: Research investment stock, EXT_STOK: Extension investment stock index, LIT_R: % of literate rural population, NARI: Natural agricultural resources index, INF: Infrastructural management index, CI: cropping intensity in %, NPRATIO: $N_2O$ and $P_2O_5$ fertilizer ratio, IRR_GW: Groundwater irrigation index, Road: Road density index, ELECT_AG: Electricity consumption for agricultural index. All variables are specified in logarithms, except those variables which are defined in percentage terms. State dummy variables have been included in both the models.

**Appendix 5 *Contd.....***

**Jowar**

**(Dependent variable: TFP index of jowar at state level)**

| Variable | Regression coefficient | Standard error | 't' statistics | Level of significance |
|---|---|---|---|---|
| | | **Model 1** | | |
| Constant | 8.14590 | 1.11845 | 7.28 | |
| RES_STOK | 0.11280 | 0.04286 | 2.63 | 0.009 |
| EXT_STOK | -0.00147 | 0.02049 | -0.07 | 0.943 |
| LIT_R | -0.67494 | 0.18133 | -3.72 | 0.000 |
| NARI | 0.11696 | 0.20277 | 0.58 | 0.565 |
| INF | -0.11583 | 0.11846 | -0.98 | 0.329 |
| RJ | -0.72636 | 0.08448 | -8.60 | 0.000 |
| MP | -1.08899 | 0.07233 | -15.06 | 0.000 |
| AP | -1.54760 | 0.06494 | -23.83 | 0.000 |
| KN | -0.87241 | 0.05245 | -16.63 | 0.000 |
| MH | -1.01832 | 0.06267 | -16.25 | 0.000 |
| Adjusted R square | 0.825 | | | |
| | | **Model 2** | | |
| Constant | 7.01453 | 2.85212 | 2.46 | |
| RES_STOK | 0.11830 | 0.04888 | 2.42 | 0.0165 |
| EXT_STOK | -0.00833 | 0.02141 | -0.39 | 0.6983 |
| LIT_R | -0.79557 | 0.20256 | -3.93 | 0.0001 |
| CI | 0.12377 | 0.59286 | 0.21 | 0.8349 |
| NPRATIO | 0.00478 | 0.09524 | 0.05 | 0.96 |
| IRR_GW | 0.21995 | 0.24158 | 0.91 | 0.3638 |
| Road | 0.04219 | 0.11335 | 0.37 | 0.7102 |
| ELECT_AG | -0.02718 | 0.045 | -0.60 | 0.5466 |
| RJ | -0.72118 | 0.09764 | -7.39 | 0.0000 |
| KN | -0.86800 | 0.08147 | -10.65 | 0.0000 |
| MP | -1.06882 | 0.08637 | -12.37 | 0.0000 |
| MH | -0.99618 | 0.07213 | -13.81 | 0.0000 |
| AP | -1.53171 | 0.06957 | -22.02 | 0.0000 |
| Adjusted R square | 0.822 | | | |

*Notes:* RES_STOK: Research investment stock, EXT_STOK: Extension investment stock index, LIT_R: % of literate rural population, NARI: Natural agricultural resources index, INF: Infrastructural management index, CI: cropping intensity in %, NPRATIO: $N_2O$ and $P_2O_5$ fertilizer ratio, IRR_GW: Groundwater irrigation index, Road: Road density index, ELECT_AG: Electricity consumption for agricultural index. All variables are specified in logarithms, except those variables which are defined in percentage terms. State dummy variables have been included in both the models.

**Appendix 5 *Contd.....***

**Bajra**

**(Dependent variable: TFP index of bajra at state level)**

| Variable | Regression coefficient | Standard error | 't' statistics | Level of significance |
|---|---|---|---|---|
| | | **Model 1** | | |
| Constant | 3.52097 | 0.89844 | 3.92 | |
| RES_STOK | 0.05143 | 0.02230 | 2.31 | 0.0187 |
| EXT_STOK | 0.02278 | 0.01438 | 1.58 | 0.1153 |
| LIT_R | 0.16232 | 0.08880 | 1.83 | 0.0695 |
| NARI | -0.26648 | 0.16950 | -1.57 | 0.1180 |
| INF | 0.37853 | 0.07868 | 4.81 | 0.0000 |
| RJ | 0.20048 | 0.06093 | 3.29 | 0.0012 |
| MH | -0.39753 | 0.05105 | -7.79 | 0.0000 |
| Adjusted R square | 0.412 | | | |
| | | **Model 2** | | |
| Constant | 7.80065 | 1.96913 | 3.96 | 0.0001 |
| RES_STOK | 0.05243 | 0.03167 | 1.66 | 0.0817 |
| EXT_STOK | 0.01315 | 0.01424 | 0.92 | 0.3574 |
| LIT_R | 0.37190 | 0.10038 | 3.70 | 0.0003 |
| CI | -0.08060 | 0.32150 | -0.25 | 0.8024 |
| NPRATIO | -0.09894 | 0.07128 | -1.39 | 0.1672 |
| IRR_GW | -1.04287 | 0.25380 | -4.11 | 0.0001 |
| Road | 0.13128 | 0.07407 | 1.77 | 0.0784 |
| ELECT_AG | 0.04863 | 0.04045 | 1.20 | 0.2311 |
| RJ | 0.24310 | 0.06446 | 3.77 | 0.0002 |
| MH | -0.51806 | 0.06374 | -8.13 | 0 |
| Adjusted R square | 0.453 | | | |

*Notes:* RES_STOK: Research investment stock, EXT_STOK: Extension investment stock index, LIT_R: % of literate rural population, NARI: Natural agricultural resources index, INF: Infrastructural management index, CI: cropping intensity in %, NPRATIO: $N_2O$ and $P_2O_5$ fertilizer ratio, IRR_GW: Groundwater irrigation index, Road: Road density index, ELECT_AG: Electricity consumption for agricultural index. All variables are specified in logarithms, except those variables which are defined in percentage terms. State dummy variables have been included in both the models.

**Appendix 5 *Contd.....***

**Gram**

**(Dependent variable: TFP index of gram at state level)**

| Variable | Regression coefficient | Standard error | 't' statistics | Level of significance |
|---|---|---|---|---|
| | | **Model 1** | | |
| Constant | 3.95002 | 0.99394 | | |
| RES_STOK | 0.09858 | 0.04309 | 2.29 | 0.0239 |
| EXT_STOK | 0.06287 | 0.0211 | 2.98 | 0.0035 |
| LIT_R | 0.20764 | 0.178 | 1.17 | 0.2457 |
| NARI | 0.15814 | 0.20001 | 0.79 | 0.4307 |
| INF | -0.12558 | 0.13027 | -0.96 | 0.3370 |
| BH | -0.09602 | 0.08609 | -1.12 | 0.2670 |
| MH | -0.15716 | 0.13021 | -1.21 | 0.2298 |
| HY | -0.33933 | 0.07889 | -4.30 | 0.0000 |
| MP | -0.37256 | 0.07015 | -5.31 | 0.0000 |
| RJ | -0.50369 | 0.07164 | -7.03 | 0.0000 |
| Adjusted R square | 0.358 | | | |
| | | **Model 2** | | |
| Constant | -10.96556 | 3.34119 | | |
| RES_STOK | 0.08843 | 0.04356 | 2.03 | 0.0341 |
| EXT_STOK | 0.06391 | 0.02034 | 3.14 | 0.0021 |
| LIT_R | 0.11284 | 0.1629 | 0.69 | 0.4899 |
| CI | 2.45268 | 0.60328 | 4.07 | 0.0001 |
| NPRATIO | -0.06407 | 0.08398 | -0.76 | 0.4471 |
| IRR_GW | 1.0306 | 0.38146 | 2.70 | 0.0079 |
| Road | 0.15244 | 0.13998 | 1.09 | 0.2784 |
| ELECT_AG | -0.05995 | 0.04529 | -1.32 | 0.1883 |
| MH | -0.01524 | 0.15874 | -0.10 | 0.9237 |
| BH | -0.22167 | 0.09258 | -2.39 | 0.0183 |
| HY | -0.32174 | 0.08926 | -3.60 | 0.0005 |
| MP | -0.34423 | 0.08104 | -4.25 | 0.0000 |
| RJ | -0.58491 | 0.09056 | -6.46 | 0.0000 |
| Adjusted R square | 0.435 | | | |

*Notes:* RES_STOK: Research investment stock, EXT_STOK: Extension investment stock index, LIT_R: % of literate rural population, NARI: Natural agricultural resources index, INF: Infrastructural management index, CI: cropping intensity in %, NPRATIO: $N_2O$ and $P_2O_5$ fertilizer ratio, IRR_GW: Groundwater irrigation index, Road: Road density index, ELECT_AG: Electricity consumption for agricultural index. All variables are specified in logarithms, except those variables which are defined in percentage terms. State dummy variables have been included in both the models.

**Appendix 5** ***Contd.....***

**Arhar**

**(Dependent variable: TFP index of arhar at state level)**

| Variable | Regression coefficient | Standard error | 't' statistics | Level of significance |
|---|---|---|---|---|
| | | **Model 1** | | |
| Constant | 5.53631 | 1.86099 | | |
| RES_STOK | 0.21483 | 0.08322 | 2.581471 | 0.0111 |
| EXT_STOK | -0.02043 | 0.03324 | -0.61462 | 0.5401 |
| LIT_R | -0.63943 | 0.33143 | -1.92931 | 0.0562 |
| NARI | 0.75538 | 0.29489 | 2.561565 | 0.0118 |
| INF | -0.39617 | 0.22688 | -1.74617 | 0.0835 |
| TN | -0.28177 | 0.14107 | -1.99738 | 0.0482 |
| GJ | -0.43246 | 0.1305 | -3.31387 | 0.0012 |
| UP | -0.48546 | 0.14021 | -3.46238 | 0.0008 |
| MH | -0.52762 | 0.10877 | -4.85079 | 0.0000 |
| MP | -0.68403 | 0.12253 | -5.58255 | 0.0000 |
| AP | -0.87407 | 0.13082 | -6.68147 | 0.0000 |
| KN | -0.94009 | 0.12763 | -7.36574 | 0.0000 |
| Adjusted R square | 0.622 | | | |
| | | **Model 2** | | |
| Constant | 0.10486 | 2.91341 | | |
| RES_STOK | 0.17174 | 0.08165 | 2.10 | 0.0412 |
| EXT_STOK | -0.02529 | 0.03112 | -0.81 | 0.4182 |
| LIT_R | -0.77585 | 0.3467 | -2.24 | 0.0273 |
| CI | 1.37264 | 0.64352 | 2.13 | 0.0352 |
| NPRATIO | 0.41427 | 0.1416 | 2.93 | 0.0042 |
| IRR_GW | 0.01827 | 0.17666 | 0.10 | 0.9178 |
| Road | -0.02492 | 0.15892 | -0.16 | 0.8757 |
| ELECT_AG | -0.16425 | 0.04631 | -3.55 | 0.0006 |
| TN | -0.26788 | 0.14992 | -1.79 | 0.0768 |
| GJ | -0.3175 | 0.14182 | -2.24 | 0.0272 |
| UP | -0.42528 | 0.14744 | -2.88 | 0.0047 |
| MP | -0.66676 | 0.1386 | -4.81 | 0.0000 |
| MH | -0.6081 | 0.12251 | -4.96 | 0.0000 |
| AP | -0.8188 | 0.14317 | -5.72 | 0.0000 |
| KN | -0.87747 | 0.13008 | -6.75 | 0.0000 |
| Adjusted R square | 0.656 | | | |

*Notes:* RES_STOK: Research investment stock, EXT_STOK: Extension investment stock index, LIT_R: % of literate rural population, NARI: Natural agricultural resources index, INF: Infrastructural management index, CI: cropping intensity in %, NPRATIO: $N_2O$ and $P_2O_5$ fertilizer ratio, IRR_GW: Groundwater irrigation index, Road: Road density index, ELECT_AG: Electricity consumption for agricultural index. All variables are specified in logarithms, except those variables which are defined in percentage terms. State dummy variables have been included in both the models.

**Appendix 5 *Contd.....***

**Moong**

**(Dependent variable: TFP index of moong at state level)**

| Variable | Regression coefficient | Standard error | 't' statistics | Level of significance |
|---|---|---|---|---|
| | | **Model 1** | | |
| Constant | 4.93854 | 1.62729 | 3.03 | 0.0032 |
| RES_STOK | -0.11342 | 0.12105 | -0.94 | 0.3514 |
| EXT_STOK | 0.10535 | 0.03981 | 2.65 | 0.0097 |
| LIT_R | 0.77594 | 0.39403 | 1.97 | 0.0521 |
| NARI | 0.13529 | 0.2802 | 0.48 | 0.6304 |
| INF | -1.03423 | 0.26056 | -3.97 | 0.0001 |
| MH | 0.65169 | 0.11554 | 5.64 | 0.0000 |
| RJ | 0.38154 | 0.15472 | 2.47 | 0.0156 |
| MP | 0.23235 | 0.11961 | 1.94 | 0.0553 |
| AP | 0.11757 | 0.11093 | 1.06 | 0.2921 |
| Adjusted R square | 0.375 | | | |
| | | **Model 2** | | |
| Constant | 6.17142 | 3.83116 | 1.61 | |
| RES_STOK | -0.08672 | 0.146649 | -0.59 | 0.5632 |
| EXT_STOK | 0.10522 | 0.04738 | 2.22 | 0.0291 |
| LIT_R | 0.59535 | 0.45192 | 1.32 | 0.1913 |
| CI | -0.49632 | 0.84161 | -0.59 | 0.557 |
| NPRATIO | 0.03971 | 0.14998 | 0.26 | 0.7918 |
| IRR_GW | 0.07609 | 0.19766 | 0.38 | 0.7012 |
| Road | -0.47401 | 0.23612 | -2.01 | 0.0479 |
| ELECT_AG | -0.15876 | 0.09091 | -1.75 | 0.0845 |
| MH | 0.65797 | 0.13259 | 4.96 | 0.0000 |
| RJ | 0.34723 | 0.16464 | 2.11 | 0.0380 |
| MP | 0.16963 | 0.13071 | 1.30 | 0.1980 |
| AP | 0.07076 | 0.12252 | 0.58 | 0.5651 |
| Adjusted R square | 0.393 | | | |

*Notes:* RES_STOK: Research investment stock, EXT_STOK: Extension investment stock index, LIT_R: % of literate rural population, NARI: Natural agricultural resources index, INF: Infrastructural management index, CI: cropping intensity in %, NPRATIO: $N_2O$ and $P_2O_5$ fertilizer ratio, IRR_GW: Groundwater irrigation index, Road: Road density index, ELECT_AG: Electricity consumption for agricultural index. All variables are specified in logarithms, except those variables which are defined in percentage terms. State dummy variables have been included in both the models.

**Appendix 5 *Contd.....***

**Urad**

**(Dependent variable: TFP index of urad at state level)**

| Variable | Regression coefficient | Standard error | 't' statistics | Level of significance |
|---|---|---|---|---|
| | | **Model 1** | | |
| Constant | 2.48988 | 1.42284 | 1.75 | |
| RES_STOK | -0.12156 | 0.06305 | -1.93 | 0.0559 |
| EXT_STOK | 0.05014 | 0.02554 | 1.96 | 0.0516 |
| LIT_R | 0.33420 | 0.26864 | 1.24 | 0.2156 |
| NARI | 0.30979 | 0.24464 | 1.27 | 0.2076 |
| INF | -0.08711 | 0.15681 | -0.56 | 0.5795 |
| MP | 0.43642 | 0.08937 | 4.88 | 0 |
| TN | 0.20831 | 0.09627 | 2.16 | 0.0322 |
| RJ | 0.16893 | 0.11121 | 1.52 | 0.1311 |
| UP | 0.08654 | 0.10959 | 0.79 | 0.4311 |
| MH | -0.12329 | 0.07821 | -1.58 | 0.1173 |
| AP | -0.69842 | 0.09164 | -7.62 | 0 |
| Adjusted R square | 0.766 | | | |
| | | **Model 2** | | |
| Constant | -0.25099 | 2.4229 | | |
| RES_STOK | -0.15949 | 0.07542 | -2.11 | 0.0363 |
| EXT_STOK | 0.07750 | 0.02542 | 3.05 | 0.0028 |
| LIT_R | 0.31317 | 0.31702 | 0.99 | 0.325 |
| CI | 0.98104 | 0.56641 | 1.73 | 0.0856 |
| NPRATIO | -0.02675 | 0.11654 | -0.23 | 0.8188 |
| IRR_GW | -0.06148 | 0.12955 | -0.47 | 0.6359 |
| Road | -0.06162 | 0.14133 | -0.44 | 0.6635 |
| ELECT_AG | -0.00469 | 0.05296 | -0.09 | 0.9296 |
| MP | 0.51005 | 0.07822 | 6.52 | 0 |
| TN | 0.28382 | 0.07883 | 3.60 | 0.0004 |
| RJ | 0.29517 | 0.09496 | 3.11 | 0.0023 |
| UP | 0.19991 | 0.09283 | 2.15 | 0.0331 |
| AP | -0.62875 | 0.07780 | -8.08 | 0 |
| Adjusted R square | 0.763 | | | |

*Notes:* RES_STOK: Research investment stock, EXT_STOK: Extension investment stock index, LIT_R: % of literate rural population, NARI: Natural agricultural resources index, INF: Infrastructural management index, CI: cropping intensity in %, NPRATIO: $N_2O$ and $P_2O_5$ fertilizer ratio, IRR_GW: Groundwater irrigation index, Road: Road density index, ELECT_AG: Electricity consumption for agricultural index. All variables are specified in logarithms, except those variables which are defined in percentage terms. State dummy variables have been included in both the models.

**Appendix 5** ***Contd.....***

**Rapeseed and Mustard**

**(Dependent variable: TFP index of rapeseed & mustard at state level)**

| Variable | Regression Coefficient | Standard error | 't' statistics | Level of significance |
|---|---|---|---|---|
| | | **Model 1** | | |
| Constant | 3.59225 | 0.91786 | 3.91 | |
| RES_STOK | 0.04293 | 0.02084 | 2.06 | 0.0384 |
| EXT_STOK | -0.00685 | 0.02174 | -0.32 | 0.7533 |
| LIT_R | 0.28420 | 0.20248 | 1.40 | 0.1628 |
| NARI | -0.02506 | 0.10011 | -0.25 | 0.8028 |
| INF | 0.01297 | 0.10953 | 0.12 | 0.906 |
| WB | 0.16146 | 0.08857 | 1.82 | 0.0706 |
| HY | 0.05850 | 0.05252 | 1.11 | 0.2674 |
| MP | -0.02149 | 0.08984 | -0.24 | 0.8113 |
| RJ | -0.07275 | 0.08265 | -0.88 | 0.3803 |
| UP | -0.06132 | 0.06281 | -0.98 | 0.3308 |
| PB | -0.06394 | 0.05605 | -1.14 | 0.2561 |
| GJ | -0.15308 | 0.07529 | -2.03 | 0.0441 |
| Adjusted R square | 0.223 | | | |
| | | **Model 2** | | |
| Constant | 3.48598 | 3.12593 | 1.12 | |
| RES_STOK | 0.05052 | 0.02062 | 2.45 | 0.0176 |
| EXT_STOK | -.006960 | 0.02247 | -0.31 | 0.7574 |
| LIT_R | 0.27606 | 0.22512 | 1.23 | 0.2224 |
| CI | 0.01105 | 0.60245 | 0.02 | 0.9854 |
| NPRATIO | -0.00275 | 0.05783 | -0.05 | 0.9621 |
| IRR_GW | -0.04758 | 0.07359 | -0.65 | 0.5191 |
| Road | 0.03469 | 0.17352 | 0.20 | 0.8419 |
| ELECT_AG | 0.02118 | 0.04331 | 0.49 | 0.6257 |
| WB | 0.20525 | 0.10865 | 1.89 | 0.0612 |
| HY | 0.10002 | 0.08999 | 1.11 | 0.2685 |
| MP | 0.02452 | 0.11593 | 0.21 | 0.8328 |
| RJ | -0.03105 | 0.11142 | -0.28 | 0.7809 |
| PB | -0.02627 | 0.0791 | -0.33 | 0.7404 |
| UP | -0.02975 | 0.08142 | -0.37 | 0.7154 |
| GJ | -0.10876 | 0.09602 | -1.13 | 0.2595 |
| Adjusted R square | 0.273 | | | |

*Notes:* RES_STOK: Research investment stock, EXT_STOK: Extension investment stock index, LIT_R: % of literate rural population, NARI: Natural agricultural resources index, INF: Infrastructural management index, CI: cropping intensity in %, NPRATIO: $N_2O$ and $P_2O_5$ fertilizer ratio, IRR_GW: Groundwater irrigation index, Road: Road density index, ELECT_AG: Electricity consumption for agricultural index. All variables are specified in logarithms, except those variables which are defined in percentage terms. State dummy variables have been included in both the models.

**Appendix 5** ***Contd.....***

**Groundnut**

**(Dependent variable: TFP index of groundnut at state level)**

| Variable | Regression coefficient | Standard error | 't' statistics | Level of significance |
|---|---|---|---|---|
| | | **Model 1** | | |
| Constant | 3.34849 | 1.57302 | 2.13 | |
| RES_STOK | 0.01779 | 0.00634 | 2.81 | 0.0103 |
| EXT_STOK | -0.02546 | 0.03406 | -0.75 | 0.4559 |
| LIT_R | -0.07081 | 0.27097 | -0.26 | 0.7942 |
| NARI | 0.25944 | 0.27391 | 0.95 | 0.3451 |
| INF | 0.16074 | 0.17925 | 0.90 | 0.3713 |
| AP | -0.25857 | 0.10672 | -2.42 | 0.0166 |
| KN | -0.30119 | 0.10387 | -2.90 | 0.0043 |
| TN | -0.55094 | 0.13705 | -4.02 | 0.0001 |
| MH | -0.41634 | 0.09449 | -4.41 | 0.0000 |
| GJ | -0.48237 | 0.09504 | -5.08 | 0.0000 |
| Adjusted R square | 0.276 | | | |
| | | **Model 2** | | |
| Constant | -0.39695 | 2.84703 | -0.139 | 0.8893 |
| RES_STOK | 0.01922 | 0.00631 | 3.05 | 0.0980 |
| EXT_STOK | -0.01011 | 0.03435 | -0.29 | 0.7688 |
| LIT_R | -0.12442 | 0.29537 | -0.42 | 0.6742 |
| CI | 1.04518 | 0.56545 | 1.85 | 0.0665 |
| NPRATIO | 0.08147 | 0.11503 | 0.71 | 0.4799 |
| IRR_GW | 0.10244 | 0.20536 | 0.50 | 0.6186 |
| Road | 0.05202 | 0.12563 | 0.41 | 0.6794 |
| ELECT_AG | -0.00559 | 0.04552 | -0.12 | 0.9024 |
| KN | -0.26426 | 0.10665 | -2.48 | 0.0143 |
| AP | -0.29976 | 0.11400 | -2.63 | 0.0095 |
| TN | -0.62441 | 0.14367 | -4.35 | 0.0000 |
| MH | -0.44778 | 0.09729 | -4.60 | 0.0000 |
| GJ | -0.51552 | 0.10024 | -5.14 | 0.0000 |
| Adjusted R square | 0.287 | | | |

*Notes:* RES_STOK: Research investment stock, EXT_STOK: Extension investment stock index, LIT_R: % of literate rural population, NARI: Natural agricultural resources index, INF: Infrastructural management index, CI: cropping intensity in %, NPRATIO: $N_2O$ and $P_2O_5$ fertilizer ratio, IRR_GW: Groundwater irrigation index, Road: Road density index, ELECT_AG: Electricity consumption for agricultural index. All variables are specified in logarithms, except those variables which are defined in percentage terms. State dummy variables have been included in both the models.

**Appendix 5 *Contd.....***

**Soybean**

**(Dependent variable: TFP index of soybean at state level)**

| Variable | Regression coefficient | Standard error | 't' statistics | Level of significance |
|---|---|---|---|---|
| | | **Model 1** | | |
| Constant | 4.65108 | 3.50618 | 1.33 | |
| RES_STOK | 0.11375 | 0.15605 | 0.73 | 0.4696 |
| EXT_STOK | 0.10310 | 0.05366 | 1.92 | 0.0608 |
| LIT_R | -0.04451 | 0.51691 | -0.09 | 0.9317 |
| NARI | 0.33519 | 0.71947 | 0.47 | 0.6435 |
| INF | -0.56701 | 0.37674 | -1.51 | 0.1390 |
| MH | 0.36736 | 0.26412 | 1.39 | 0.1708 |
| MP | 0.26850 | 0.1941 | 1.38 | 0.1731 |
| RJ | 0.12627 | 0.19783 | 0.64 | 0.5264 |
| Adjusted R square | 0.347 | | | |
| | | **Model 2** | | |
| Constant | -13.83681 | 7.44618 | -1.86 | |
| RES_STOK | -0.06574 | 0.18279 | -0.36 | 0.7208 |
| EXT_STOK | 0.13567 | 0.04956 | 2.74 | 0.0089 |
| LIT_R | 0.08630 | 0.50892 | 0.17 | 0.8661 |
| CI | 4.30083 | 1.45540 | 2.96 | 0.0050 |
| NPRATIO | -0.36173 | 0.36097 | -1.00 | 0.3218 |
| IRR_GW | -0.04384 | 0.70598 | -0.06 | 0.9508 |
| Road | 0.20977 | 0.34913 | 0.60 | 0.5510 |
| ELECT_AG | -0.23876 | 0.12622 | -1.89 | 0.0651 |
| RJ | -0.07814 | 0.29175 | -0.27 | 0.7901 |
| MH | -0.25249 | 0.43187 | -0.58 | 0.5618 |
| MP | -0.11382 | 0.32387 | -0.35 | 0.7269 |
| Adjusted R square | 0.479 | | | |

*Notes:* RES_STOK: Research investment stock, EXT_STOK: Extension investment stock index, LIT_R: % of literate rural population, NARI: Natural agricultural resources index, INF: Infrastructural management index, CI: cropping intensity in %, NPRATIO: $N_2O$ and $P_2O_5$ fertilizer ratio, IRR_GW: Groundwater irrigation index, Road: Road density index, ELECT_AG: Electricity consumption for agricultural index. All variables are specified in logarithms, except those variables which are defined in percentage terms. State dummy variables have been included in both the models.

**Appendix 5 *Contd.....***

**Cotton**

**(Dependent variable: TFP index of cotton at state level)**

| Variable | Regression coefficient | Standard error | 't' statistics | Level of significance |
|---|---|---|---|---|
| | | **Model 1** | | |
| Constant | 4.88782 | 1.03294 | 4.73 | |
| RES_STOK | 0.07159 | 0.03075 | 2.33 | 0.0206 |
| EXT_STOK | 0.00212 | 0.01682 | 0.13 | 0.8999 |
| LIT_R | 0.55920 | 0.14588 | 3.83 | 0.0002 |
| NARI | -0.54010 | 0.19840 | -2.72 | 0.0069 |
| INF | -0.03077 | 0.14175 | -0.22 | 0.8283 |
| HY | 0.14571 | 0.06273 | 2.32 | 0.0209 |
| RJ | 0.12534 | 0.08671 | 1.45 | 0.1494 |
| AP | 0.06909 | 0.07030 | 0.98 | 0.3266 |
| KN | -0.08103 | 0.05960 | -1.36 | 0.1750 |
| MH | -0.24778 | 0.06781 | -3.65 | 0.0003 |
| PB | -0.49352 | 0.06763 | -7.30 | 0.0000 |
| MP | -0.55801 | 0.07454 | -7.49 | 0.0000 |
| GJ | -0.59897 | 0.07696 | -7.78 | 0.0000 |
| Adjusted R square | 0.456 | | | |
| | | **Model 2** | | |
| Constant | 4.84207 | 1.75712 | 2.76 | |
| RES_STOK | 0.08569 | 0.03331 | 2.57 | 0.0146 |
| EXT_STOK | 0.00193 | 0.01572 | 0.12 | 0.9022 |
| LIT_R | 0.51127 | 0.17380 | 2.94 | 0.0035 |
| CI | 0.08249 | 0.36291 | 0.23 | 0.8204 |
| NPRATIO | -0.13517 | 0.08377 | -1.61 | 0.1077 |
| IRR_GW | -0.70316 | 0.24638 | -2.85 | 0.0046 |
| Road | 0.34258 | 0.11713 | 2.92 | 0.0037 |
| ELECT_AG | -0.15652 | 0.03283 | -4.77 | 0.0000 |
| HY | 0.12376 | 0.07518 | 1.65 | 0.1009 |
| RJ | 0.11420 | 0.08774 | 1.30 | 0.1942 |
| AP | 0.00526 | 0.06906 | 0.08 | 0.9394 |
| KN | -0.16370 | 0.06879 | -2.38 | 0.0180 |
| MH | -0.39630 | 0.07428 | -5.34 | 0.0000 |
| GJ | -0.46959 | 0.07948 | -5.91 | 0.0000 |
| PB | -0.49812 | 0.07114 | -7.00 | 0.0000 |
| MP | -0.68712 | 0.07597 | -9.04 | 0.0000 |
| Adjusted R square | 0.506 | | | |

*Notes:* RES_STOK: Research investment stock, EXT_STOK: Extension investment stock index, LIT_R: % of literate rural population, NARI: Natural agricultural resources index, INF: Infrastructural management index, CI: cropping intensity in %, NPRATIO: $N_2O$ and $P_2O_5$ fertilizer ratio, IRR_GW: Groundwater irrigation index, Road: Road density index, ELECT_AG: Electricity consumption for agricultural index. All variables are specified in logarithms, except those variables which are defined in percentage terms. State dummy variables have been included in both the models.

**Appendix 5** ***Contd.....***

**Jute**

**(Dependent variable: TFP index of jute at state level)**

| Variable | Regression coefficient | Standard error | 't' statistics | Level of significance |
|---|---|---|---|---|
| | | **Model 1** | | |
| Constant | 2.30015 | 1.04009 | 2.21 | |
| RES_STOK | -0.02310 | 0.04423 | -0.52 | 0.6025 |
| EXT_STOK | 0.02319 | 0.02735 | 0.85 | 0.3983 |
| LIT_R | 0.14419 | 0.25185 | 0.57 | 0.5681 |
| NARI | 0.17598 | 0.06803 | 2.59 | 0.0110 |
| INF | 0.18368 | 0.09458 | 1.94 | 0.0546 |
| AS | 0.07536 | 0.08052 | 0.94 | 0.3513 |
| WB | -0.01276 | 0.05999 | -0.21 | 0.8319 |
| BH | -0.43474 | 0.09569 | -4.54 | 0.0000 |
| Adjusted R square | 0.653 | | | |
| | | **Model 2** | | |
| Constant | -0.36505 | 1.73978 | -0.21 | |
| RES_STOK | -0.03514 | 0.0472 | -0.74 | 0.4583 |
| EXT_STOK | 0.01740 | 0.02883 | 0.60 | 0.5474 |
| LIT_R | 0.27912 | 0.25442 | 1.10 | 0.2751 |
| CI | 0.62834 | 0.31309 | 2.01 | 0.0473 |
| NPRATIO | 0.05858 | 0.04644 | 1.26 | 0.2098 |
| IRR_GW | 0.07536 | 0.05266 | 1.43 | 0.1553 |
| Road | 0.05672 | 0.07157 | 0.79 | 0.4298 |
| ELECT_AG | 0.00643 | 0.03251 | 0.20 | 0.8435 |
| AS | 0.11380 | 0.10539 | 1.08 | 0.2826 |
| WB | 0.05060 | 0.07124 | 0.71 | 0.4791 |
| BH | -0.44562 | 0.09968 | -4.47 | 0.0000 |
| Adjusted R square | 0.652 | | | |

*Notes:* RES_STOK: Research investment stock, EXT_STOK: Extension investment stock index, LIT_R: % of literate rural population, NARI: Natural agricultural resources index, INF: Infrastructural management index, CI: cropping intensity in %, NPRATIO: $N_2O$ and $P_2O_5$ fertilizer ratio, IRR_GW: Groundwater irrigation index, Road: Road density index, ELECT_AG: Electricity consumption for agricultural index. All variables are specified in logarithms, except those variables which are defined in percentage terms. State dummy variables have been included in both the models.

**Appendix 5 *Contd.....***

**Sugarcane**

**(Dependent variable: TFP index of sugarcane at state level)**

| Variable | Regression coefficient | Standard error | 't' statistics | Level of significance |
|---|---|---|---|---|
| | | **Model 1** | | |
| Constant | 5.33705 | 0.8987 | 5.94 | |
| RES_STOK | -0.00776 | 0.03052 | -0.25 | 0.0237 |
| EXT_STOK | 0.02685 | 0.0124 | 2.17 | 0.0317 |
| LIT_R | -0.28482 | 0.14465 | -1.97 | 0.0505 |
| NARI | 0.08517 | 0.15451 | 0.55 | 0.5822 |
| INF | 0.02905 | 0.10398 | 0.28 | 0.7803 |
| MH | 0.07991 | 0.03892 | 2.05 | 0.0415 |
| TN | 0.07423 | 0.03819 | 1.94 | 0.0535 |
| HY | -0.07715 | 0.04057 | -1.90 | 0.0588 |
| UP | -0.21053 | 0.05229 | -4.03 | 0.0001 |
| AP | -0.25783 | 0.05062 | -5.09 | 0.0000 |
| BH | -0.47211 | 0.05131 | -9.20 | 0.0000 |
| Adjusted R square | 0.499 | | | |
| | | **Model 2** | | |
| Constant | 5.82870 | 2.04245 | 2.85 | |
| RES_STOK | 0.00190 | 0.0358 | 0.05 | 0.0194 |
| EXT_STOK | 0.03090 | 0.01173 | 2.63 | 0.0092 |
| LIT_R | -0.17683 | 0.19148 | -0.92 | 0.3570 |
| CI | 0.06311 | 0.38173 | 0.17 | 0.8689 |
| NPRATIO | 0.07720 | 0.06500 | 1.19 | 0.2366 |
| IRR_GW | -0.19982 | 0.20847 | -0.96 | 0.3392 |
| Road | -0.02817 | 0.09394 | -0.30 | 0.7646 |
| ELECT_AG | -0.02594 | 0.02576 | -1.01 | 0.3154 |
| TN | 0.07720 | 0.05351 | 1.44 | 0.1509 |
| MH | 0.05444 | 0.04171 | 1.31 | 0.1935 |
| HY | -0.05838 | 0.04119 | -1.42 | 0.1582 |
| UP | -0.18554 | 0.05881 | -3.15 | 0.0019 |
| AP | -0.25789 | 0.05542 | -4.65 | 0.0000 |
| BH | -0.43476 | 0.07210 | -6.03 | 0.0000 |
| Adjusted R square | 0.498 | | | |

*Notes:* RES_STOK: Research investment stock, EXT_STOK: Extension investment stock index, LIT_R: % of literate rural population, NARI: Natural agricultural resources index, INF: Infrastructural management index, CI: cropping intensity in %, NPRATIO: $N_2O$ and $P_2O_5$ fertilizer ratio, IRR_GW: Groundwater irrigation index, Road: Road density index, ELECT_AG: Electricity consumption for agricultural index. All variables are specified in logarithms, except those variables which are defined in percentage terms. State dummy variables have been included in both the models.

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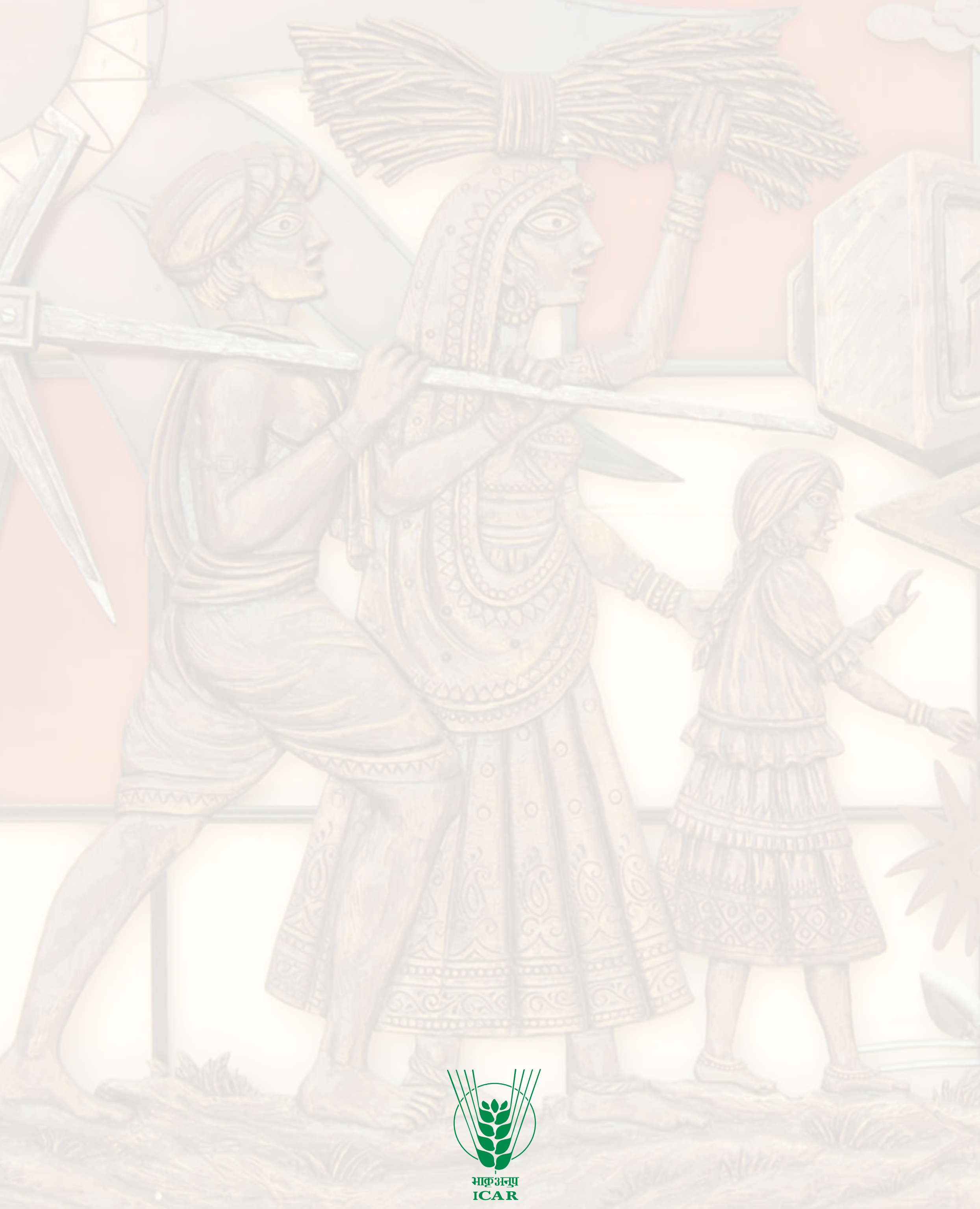


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