Irrigation and other Factors Contribution to the Agricultural Growth and Development in India: A Cross-State Panel Data Analysis for 1970 to 94[1]

Madhusudan Bhattarai[2] and A. Narayanamoorthy[3]

1. Introduction

The major objective of this study is to better analyze the factors contributing to multifactor agricultural productivity (Total factor productivity) and production growth in India. This study quantifies the incremental benefits of major factor inputs (such as, irrigation, crop technology and infrastructures) in over time variation of agricultural performance and agricultural productivity across the states in India and then it discussed the policy implications of these findings. This is done using annual time series and cross section data of 14 major states of India for the period of 1970 to 1995, which accounts for more than 90 % of the agrarian economy of the country. It adopts fixed effect panel model with weighted least squared estimation technique (Generalized Least Square technique) to correct for scale and size effect related biases associated with state level aggregate data series across the states in India. In addition, we have also used here actually farm-level realized indicators of factor inputs in explaining the variation of agricultural performance unlike in the previous studies on the topic that used the government spending in each sector (Fan, et al., 2000 and 1999; Evenson, et al., 1999) to assess the factors contribution on productivity growth. Therefore, this study contributes to methodological refinement as well as providing an improved policy information on factors responsible for the interstate variation for agricultural productivity growth in India over the two and half decades.

2. Recent controversies on incremental marginal impact of irrigation

The incremental effect of factor inputs has been one of the controversial issues in literature of rural development. Declining international food prices have raised questions on the commonly held perception on usefulness of several factor inputs (such as, irrigation, road, agriculture research, extension, etc.) in agriculture growth, and past policy thrust for maintaining regional food security (food production). Details discussions on these issues and different results on incremental factors' contribution to agricultural growth in India are found in WCD (2000); Fan, *et al.*, (2000); Bhalla and Singh (2001); Dhawan (1988; 2000), etc.

In fact, the World Commission on Dam Report (WCD 2000) says that there are no reliable empirical estimates available separating out the marginal impact of irrigation from that of other policy and technology factors. In the case study of India, the World Commission on Dams (WCD, 2000) report says that only 10 percent share of the total increased in food production from 1950 to 1993 is attributable to additional land brought under irrigation and the rest of growth in food production is by changes in other factors (p.100). While analyzing the factors contribution to the agricultural productivity in India, Fan et al., (2000) earlier have reported that marginal impact of government spending on irrigation is less than 1/6th of the marginal impact of government spending on agriculture sector Research and Development (p.1049), with the elasticity of governmental spending in irrigation and agricultural sector R&D as 0.036 and 0.255, respectively. But subsequent analysis in India have found contrasting results, for example (Deb Roy and

---

[1] A summary version of a research paper presented at the IWMI- TATA annual workshop in Anand, Gujarat, India, January, 27-29, 2003. The full paper can be obtained from the first author. ** This is a part of the on-going study on *Irrigation Impact Study* in India sponsored by the International Water Management Institute, Sri Lanka, under its Comprehensive Assessment program, financial supports of which is provided by the Government of the Netherlands. Part of the research fund for India study is also provided by IWMI-TATA program of IWMI-India office supported by Sri Ram TATA Trust Fund, Mumbai.

[2] Postdoctoral Scientist (Economist), International Water Management Institute, P. O. Box 2075, Colombo, Sri Lanka (*E-mail:* m.bhattarai@cgiar.org.
[3] Reader, Gokhale Institute of Politics and Economics (Deemed to be a University), Pune – 411 004, India (*E-mail:* na_narayana@hotmail.com).

Shah, 2003; Dhavan, 2000; Bhalla and Singh, 2001), and the previous studies on the related topics in India (such as, Vaidhyanathan, et al., 1994; Dhavan, 1998) have reported different findings on factors contribution to agricultural productivity growth.

Dhawan (2000) reported that on an average an irrigated farmer in India obtained about Rs. 14,000 per crop hectare cultivated land whereas the average rainfed farmer can only obtained about Rs. 6,000 per hectare (in constant price of 1992-93). The difference on gross farm returns between irrigated and rainfed farming then comes to an average of about US$ 250/ha (in exchange rate of 1993). Likewise, Deb Roy and Shah (2003) using the districts level analysis have reported that the marginal incremental benefit (gross value of crops output) of surface irrigated crop land in India is Rs. 1,237/ha in 1992-93 (in constant price of 1992-93) higher than the crops area without access to irrigation, holding impacts of fertilizers and other factor inputs constant across the districts (p.12).

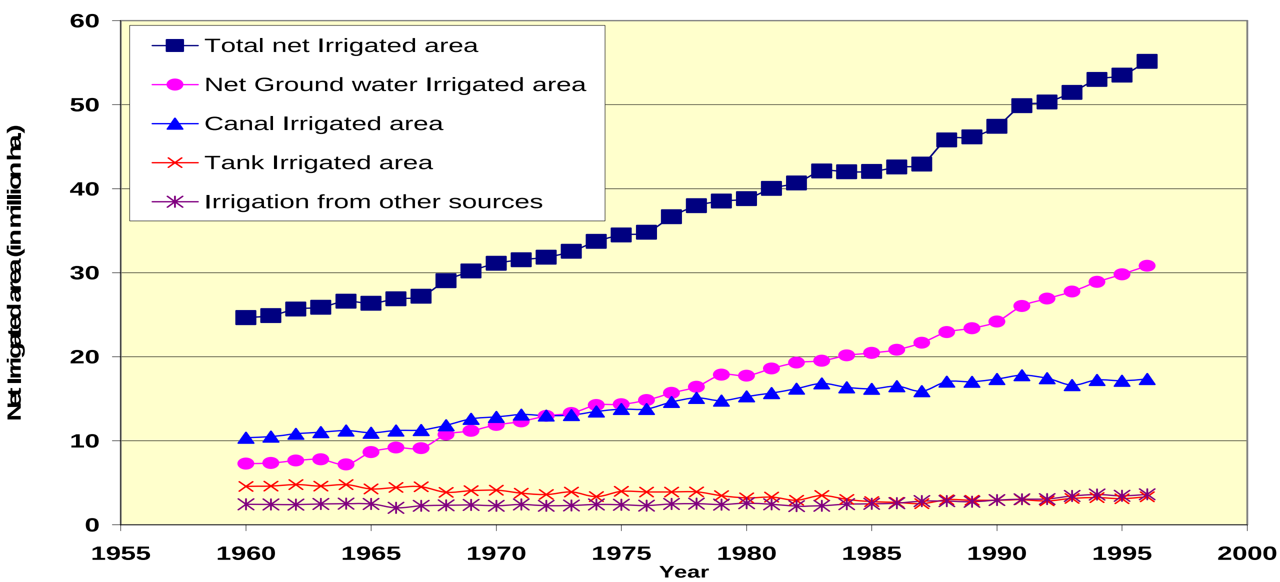
Because of these differences on findings in the past studies on irrigation impact, an effort is made in this paper to correctly separate out the contribution (marginal impact) of irrigation development and other factor inputs to the agricultural productivity growth in India. By doing so, this study also attempts to fill one of the gaps in the literature on assessment on performance of irrigation and on estimation of aggregate marginal incremental benefits (impacts) of irrigation development. The results derived in this study is also expected to contribute to better inputs on policy dialogue on factors relative contribution in improving agricultural productivity and agricultural growth and development in general.

3. Results and Discussions

3.1 Recent changes in structure of irrigation in India

Though the main objective of the paper is to estimate the contribution of irrigation and other factors in the agricultural productivity, it is important to understand the changes that have taken place in irrigation development in India since 1970. Figure 1, illustrates the major structural changes that have taken place in the development of irrigation over the last three and half decades in India.

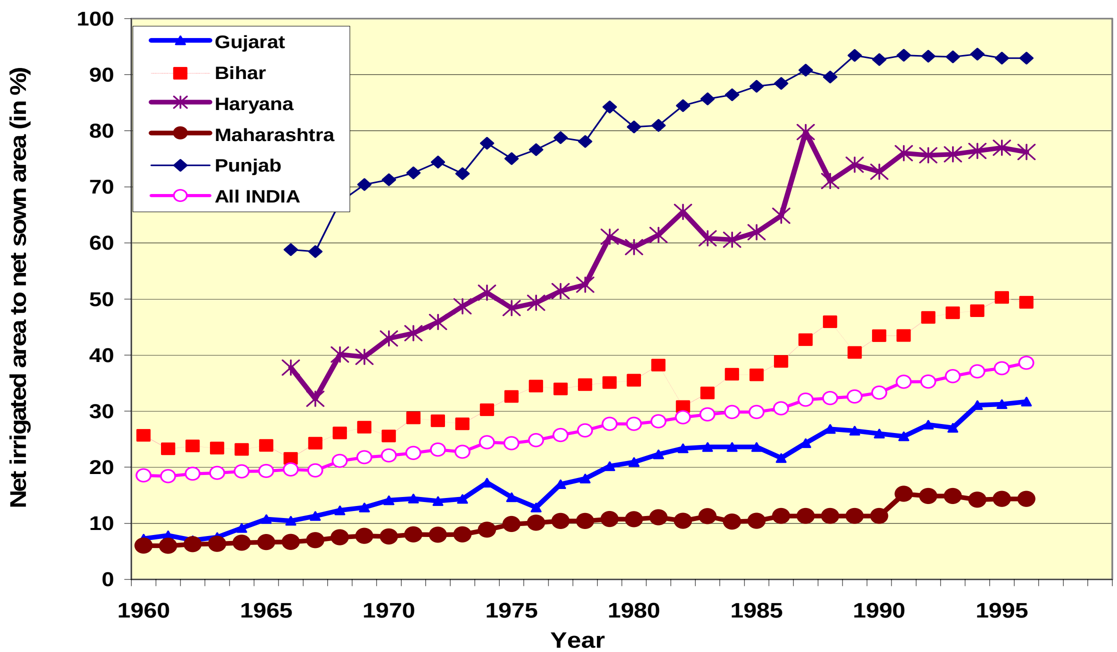
Figure 1. Changes in Net Irrigated Area at all India level (in million ha), 1960-96.



The canal irrigated area was larger than groundwater irrigated area until 1972-73, but now groundwater irrigated area is nearly double than that of canal irrigated area. About 5 million hectares of additional canal irrigated hectares (net irrigated area) were added during 1970 to 1996, whereas more than 20 million hectares of net groundwater irrigated area were added during the same period (figure 1). There is a continuous decline in area irrigated by tank and other sources over the years

As observed at the national level, structural changes have also taken place across different states in India. Overtime changes in the net irrigated area with respect to the net sown area across selected states are illustrated in the figure 2. Some of the agriculturally developed states like Punjab and Haryana have got relatively higher share of percentage of net irrigated crop area than other states, but the irrigated area is not the only one factor for the development of agriculture and that of the state economy in general, as illustrated by the relatively lower percent of net irrigated area of Maharashtra and Gujarat- that are relatively well-off states in India than others. The percent of irrigated crop area of Punjab is above 93 % in 1995, which is more than double than that of the percent of net irrigated crop area at all India level. Similarly the structural changes in irrigation sector across the 14 states of India, in particular, how the gross irrigated area, ground water irrigated area, and pump numbers are added across the states in India over the two and half decades (1970 to 94), are shown in table 1. The rate of expansion on ground water irrigated area and pump numbers in the eastern India (West Bengal) are phenomenally high than rest of the other state in India. On an average of half a million of pumps are annually added in West Bengal during the period of 17 years from 1972 to 1987. In fact, more than one-third of total pumps number in India in early 1990 were in the state of West Bengal alone (table 1). Detailed discussions on this issue on ground water expansion and pumps revolutions in eastern India are also found in Shah, 2001, and in Deb Roy and Shah, 2003.

Figure 2. Percentage of net irrigated area to net sown area across selected states in India, 1960-1999.

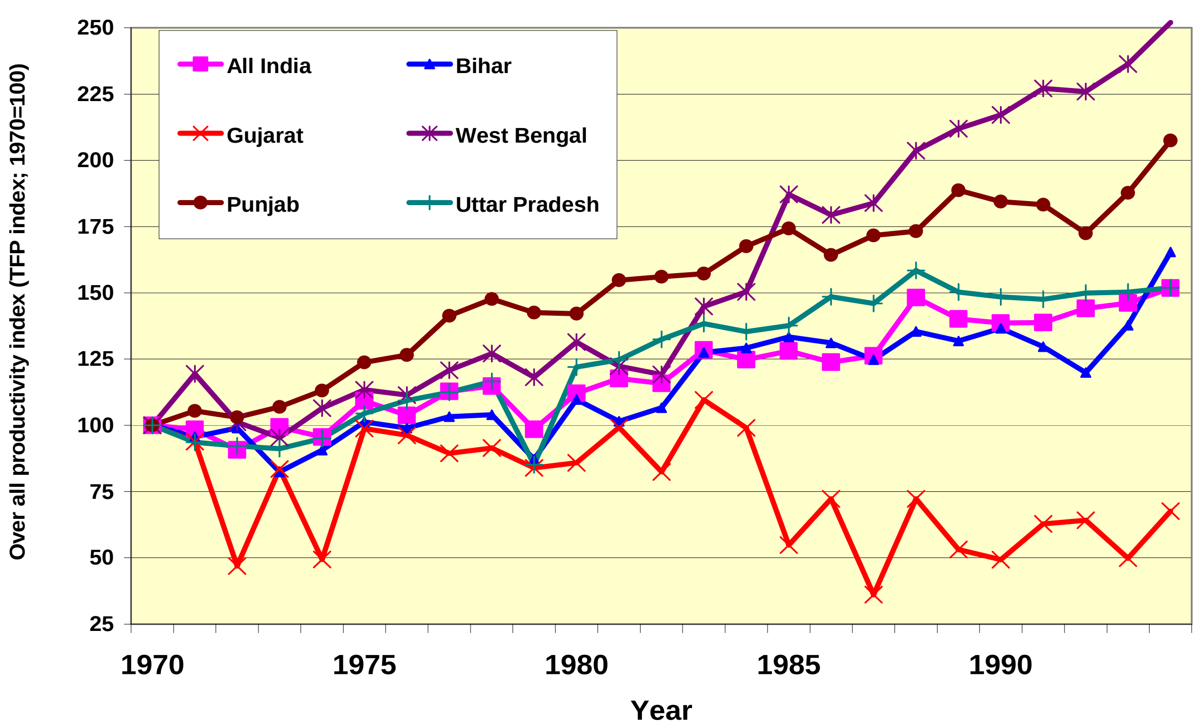


Changes taken place in the development of total and source wise irrigation (structural changes) over the years across the states must have played a significant role in increasing the agricultural productivity, that also significantly vary across the states (se figure 3 below). Therefore, an attempt is made here to assess the average contribution of irrigation vis-à-vis other factors to the growth of multifactor productivity in agriculture as well partial productivity (production growth) across the state which is applicable to all India level. This is done using statistical analysis (panel regression analysis), which provides us better pictures on the over time changes in the above relationship between agricultural productivity and factor inputs.

B. Regression results with factors contribution to agricultural productivity

The regression results in table 1, from a time series and cross section (states) analysis, show marginal impact of selected factor inputs on the variation of two different indicators of agricultural productivity. They are: overall productivity growth (productivity model) created by taking into account of all factor inputs used in agriculture (Multifactor Productivity Model in table 2). The other is over all changes in total production level (Production Model). The elasticity value which estimates the factor inputs in percentage terms (unit free measurement) is also shown in the right hand side of each of the marginal impact. The multifactor agricultural productivity, or agricultural productivity of all factor inputs taken together (TFP index; 1970= 100 index) is defined as growth in all crops and livestock outputs minus growth in all agricultural inputs in a year (estimated separately for a state), and it measures the overall technical and economic efficiency (and technical change) in agriculture production process, not just increased crops yield. Hence, the overall productivity measured by changes in TFP index here is different than the commonly measured crop productivity indicator such as crop yield (or land productivity). Whereas, the production index (1970=100) is estimated here with gross value returns of 19 major crop and 3 major livestock in each states of India, which is in principle equivalent to the land productivity (gross value returns, or partial productivity of crop lands). The over all productivity index (TFP index) and production index used in this study were estimated earlier by IFPRI researchers and provided in Fan, *et. al.*, (1999). The variation of over all productivity taking into all inputs (TFP index) across selected states of India is shown in figure 3 below.

Figure 3. Changes on multifactor productivity (TFP) across selecetd states in India, 1970-94.



The regression results reported in table 2 imply that two factors namely irrigation and rural literacy level, with elasticity of 0.33 and 0.41 respectively, played a very critical role in explaining the inter-state variation of the agricultural productivity (TFP index) in India over the last 25 years (1970-94), more than any other factor inputs selected in this study. This implies that the future growth of agriculture in India may also heavily depend on the performance of the irrigated agriculture and the level of improvement in rural sector human capital to efficiently utilize the potential created in the irrigated agriculture.

The higher marginal impact of rural literacy variables in this study illustrates the increasing importance of human capital development in agricultural growth and development (Shultz, 1961). This also reflects the changes of farming in India from subsistence based production to knowledge and skill based rural economy over the years. In addition, factors like fertilizers, HYV and road infrastructures have also played an important role on increasing the over all efficiency and productivity of agriculture sector in India.

When we included the ground water factor in the above model, the incremental impact of groundwater source of irrigation is very significant in explaining the interstate variation of agricultural production (yield) and overall productivity of all inputs use (TFP index). The marginal impact of ground water is however more noticeable in the case of interstate changes in production index (with elasticity of 0.23) rather than the changes in multifactor productivity index (with elasticity of 0.09)[4]. This implies that though groundwater irrigation is significant for improving the growth of production (or crops yield), its impact on overall returns, or resources use efficiency, in farming is relatively low. This could be possibly because of relatively higher farmers' level cost of cultivation under groundwater source of irrigation than in irrigation from surface sources. The decreasing trend of TFP index (productivity of al inputs use) of Gujarat in figure 3 above also clearly illustrates this fact.

The marginal impact of Fertilizer use and HYVs adoption is lower in interstate variation of over all productivity (change in TFP index) than in the variation of total production level. The impact of improved crop varieties (HYVs adoption) was increasing at rising rate up to 1980 and thereafter the impact of other policy and infrastructural factors on agriculture productivity has started to increase more than the HYV adoption in the Indian economy (details discussions in the full paper).

The marginal impact of road infrastructures on interstate variation of the agricultural production level (in index) is negative, which is contradictory to our prior held hypothesis. To investigate further on this negative relation with road, we again estimated the production model with two road variables, Road and "Road squared term". Where the road term was positive and the road squared term was negative, and both the terms were statistically significant. That means there is a no straight but a curve linear relationship between agricultural production growth and road factor across the states in India during 1970 to 1994. The agricultural production was positively affected by the road infrastructure in the state with relatively low level of road infrastructures, but the important of road density (i.e., increases in permanent rural road density) declined as the basic level of road access (permanent road) is met. The cursory look at the rural road and production index data series across the states also supports this fact.

By using the actually realized indicators of factor inputs on variation of key agricultural sector productivity and performances than the level of sectoral governmental spending used in the past studies, this study has factored out the incremental marginal impact of factor inputs in a better way than the available in the past studies. This study has also address some of the issues on marginal facto contribution in agriculture that were not address (unresolved) earlier by the World Commission on Dam Report (WCD, 2001). The findings from this study contribute for methodological development on estimation of factors contribution in agriculture productivity growth, and for designing an effective and efficient investment and financing policies in irrigation and other sectors of agriculture and rural development in general. The research findings are equally applicable in the context of other developing countries, even outside of India, with similar constraints and opportunities for agricultural and rural development.

[4] Details of the empirical results on source of irrigation impacts on agricultural production and productivity discussed in this paragraphs are provided in the full paper, from which only summary has been reported in the policy brief. The detailed empirical results and research paper can be obtained from the authors of this paper.

Table 2:

Factors responsible for variation of multifactor productivity of all factor inputs (TFP index) and Production level across the states in India, 1970-1994.

Dependent variable:

1. **Multifactor Productivity Model**: Productivity of all inputs taken together (TFP) index in each state, 1970 = 100.

2. **Production Model**: Agricultural production in index level in each state, 1970=100

Independent Variable	**Multifactor Productivity Model**	Elasticity value	**Production Model**	Elasticity Value
Time Trend	-0.35 (0.01)^{NS}		-0.21 (0.44)^{NS}	
% of gross cropped area under irrigation (GIA/GCA)	1.2 (5.25)***	0.33	0.44 (1.74)*	0.11
Fertilizer use per cropped area (in Kg/ha)	0.10 (1.62)	0.04	0.34 (5.26)***	0.12
HYV adoption rate (in %)	0.18 (1.61)	0.06	0.27 (2.16)**	0.08
Rural literacy rate (%)	1.59 (4.84)***	0.41	4.62 (8.17)***	1.07
Road density) (in Km/1000Km^2 land)	0.03 (3.87)***	0.13	-0.03 (2.6)***	-0.12
Adjusted R^2 (Un-weighted)	0.68		0.80	
Number of states used	14		14	
Number of observations	350		350	

Notes: 1). Values in parentheses are absolute t-statistics; * - significant at 10 percent; ** - significant at 5 percent; *** - significant at 1 percent. F statistics of all above models are significant at 1percent.

2). Both models were estimated fixed effects panel model using Weighted Least Squares (GLS model) techniques. The GLS model was further iterated to minimize the Mean Sum Squared Error, and the results from the converged models are reported here.

3). TFP index is growth in output minus growth in all inputs used in agricultural production process, and it represents overall efficiency in production process. Production index here includes the outputs of 19 crops and 3 livestock sectors.

4. Elasticity value in economics is unit free measurement of factors impacts on dependent variable, estimated at the sample mean of all the observations.

5. Different forms of Models are also explored, the signs of variables have not changed in different alternate models (detailed results from alternate regression models are in Bhattarai and Narayanamoorthy, forth coming).

References

Bhattarai M. and A. Naryanamoorthy, (forth coming). Irrigation Impact on Agricultural Productivity Growth, Returns and Performance in India: Cross-state Panel data analysis for 1970-94. IWMI Working paper under Comprehensive Assessment Program. IWMI: Colombo, Sri Lanka.

Bhalla, G. S. and G. Singh. 2001. Indian Agriculture: Four decades of Development. Sage Publications, India

Central Water Commission (CWC), 1998. *Water and Related Statistics*. Government of India Publication. CWC. New Delhi, India.

Deb Roy A. and T. Shah (2003), 'Socio-Ecology of groundwater irrigation in India', in Llamas R and E. Custodio (eds) *Intensive Use of Groundwater: Challenges and Opportunities*, Swets and Zetlinger Publishing Co., The Netherlands, pp. 307-336

Dhawan, B. D. 1988. *Irrigation in India's Agricultural Development: Productivity, Stability, Equity*, Sage Publications India, New Delhi, India.

_____________. 2000. Economic Impact of Major Water Resources projects on farm Economy of India. Agricultural Situation in India. December 2000. (also published in Viswam, January – March, 2001).

Fan S., P. Hazel, and T. Sukhadeo , 1999. *Linkages between Government Spending, Growth, and Poverty in Rural India.* Research Report No 110. International Food Policy Research Institute: Washington D.C., USA., Washington DC.

____________________________.2000. Government Spending, Growth and Poverty in Rural India. American Journal of Agricultural Economics. November (page. 1038-51)

Evenson, R.; C. Pray, M. Rosegrant, 1999. *Agricultural Research and Productivity Growth in India*, Research Report No 109, International Food Policy Research Institute, Washington D.C., USA

Shah, T. 2001. Wells and Welfare in the Ganga Basin: Public Policy and private Initiative in Eastern Uttar Pradesh, India. IWMI Research Report, Number 54. International Water Management Institute: Colombo, Sri Lanka

Shultz, T. 1961. Investment in Human Capital. American Economic Review. Vol. 51 (1). March.

Vaidyanathan, A., A. Krishnakumar; A. Rajagopala and D. Varatharajan, 1994. Impact of Irrigation on Productivity of Land. *Journal of Indian School of Political Economy*. Vol. 6 No. 4. October-December.

World Commission on Dams, 2000. *Dams and Development: A New Framework for Decision-Making*, Earthscan Publishers, London, UK.

Table 1: Changes on multifactor productivity (TFP) and structures of irrigation development across the states in India during 1970-1994.

States	% change on TFP index, 1970 to 1994. (1970 = 100 index)	% of gross crop irrigated areas		% of groundwater e irrigated area		Total No. of pumps (in millions)		Annual avg. growth (in %).	annual .avg. tot. pumps. Added (1000)
		1970	1994	1970	1994	1972	1992		
1. Andhra Pradesh	33	30	43	15	40	0.256	1.1	16.5 %	41.74
2. Bihar	65	28	40	26	50	0.095	0.671	30%	28.8
3. Gujarat	-32	14	27	79	79	0.414	0.631	2.6%	10.83
4. Haryana	60	40	77	38	49	0.115	0.504	17%	19.5
5. Himachal Pradesh	12	15	18	1	12	0.0002	0.002	45%	0.10
6. Karnataka	32	13	26	23	35	0.199	0.611	10.4%	20.6
7. Madhya Pradesh	46	9	19	38	54	0.113	0.925	36 %	40.6
8. Maharashtra	50	9	11	57	61	0.342	1.19	12.4	42.3
9. Orissa	98	17	18	4	40	0.006	0.038	26.7%	1.58
10. Punjab	108	75	93	55	61	0.327	0.714	6%	19.4
11. Rajasthan	19	15	30	51	61	0.072	0.885	56%	40.7
12. Tamil Nadu	40	47	46	30	51	0.888	1.21	2%	16
13. Uttar Pradesh	52	38	58	56	70	0.309	2.282	10%	98.6
14. West Bengal	152	24	31	1	37	0.007	7.7*	7000%	512*
All India level average	52	23	34	38	55	3.163	19.0	80%	775

Note. 1). Data sources: Economics intelligence unit, CMIE, 1999. Bombay; CWC, 1998; Fan et al., 1999.
2). * refers to the total pump number in 1987 because of unavailability of data for 1992.

Explanations: This table 1 shows the state level changes in multifactor agricultural productivity (TFP), and the corresponding percentage changes in gross crops irrigated area and in percentage of groundwater water irrigated area during the period of 1970 to 1994. This table clearly illustrates that the impact of overall irrigation and of ground water irrigation is not same across the states in India. The annual average increases in pumps number for all India level was about 80% between 1970 to 1994 including West Bengal, whereas, it was 20% per annum when we exclude West Bengal from the sample.