Original Article

Public Investment in Agricultural Research and Extension in India

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Abstract Earlier studies have empirically illustrated the significant role that investment in agricultural research and extension (R&E) plays in enhancing productivity, accelerating agricultural growth and reducing poverty in India. This article adds to the existing literature on the spatial and temporal dimensions of agricultural R&E investments with special emphasis on returns to investment in major states of India. The study reveals that significant structural changes have occurred in the pattern of agricultural R&E investments across sectors and states over the past five decades. R&E investments on the crop and fishery sectors improved over time at the expense of the livestock sector. Similarly, the states' share in aggregate R&E investments declined over the years, while the centre's improved proportionately. Returns to investments differed significantly according to geography, with the states that had a higher share of total factor productivity growth in their output growth faring better than the rest in relative terms. The R&E investment in the crop sub-sector in India has been especially rewarding, generating returns that are close to 50 per cent. In general, the findings of the study suggest the engineering of a deliberate shift in focus from alternative types of investment to agricultural R&E to meet the future growth challenges in India's agriculture sector.

D'autres études précédents ont illustré de façon empirique le rôle que les investissements en recherche et extension agriculturale (en anglais: R&E) en Inde ont eu sur l'amélioration de la productivité, sur la croissance agricole, et sur la réduction de la pauvreté. Cette étude complémente la littérature existante en étudiant les dimensions spatiales et temporelles des investissements R&E, en particulier le retour sur investissements, dans le secteur agricultural en Inde. Cette étude révèle que, dans les cinq dernières décades, des changements structurels importants ont eu lieu dans le modèle des investissements en R&E agricultural dans plusieurs secteurs et régions Indiens. Les investissements R&E dans les secteurs des récoltes et pécheur ont augmenté au long du temps, au détriment du secteur du bétail. La proportion des investissements fait par le centre a augmenté, tandis que la proportion des investissements faits dans l'ensemble par les états a chuté. Le retour sur investissement est assez différent parmi les régions géographiques: les états indiens ou il y a une proportion plus grande de la croissance de la production du a une croissance de la productivité totale des facteurs, ont bénéficié relativement plus que d'autres états. L'investissement R&E dans le secteur des récoltes a été particulièrement intéressant, avec des rendements de presque 50%. En général, les résultats de cette étude suggèrent que, pour faire face aux défis de croissance agricole en Inde, il faudrait réaliser un changement dans le secteur de l'investissement, se focalisant sur l'investissement en R&E agricultural, plutôt que sur d'autres alternatives.

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Introduction

The agricultural research and extension (R&E) system of India is acclaimed for its significant role in transforming the country's status from food-importing to food-secure in a relatively short time. This transformation is mainly attributed to substantial investments incurred in strengthening the National Agricultural Research and Extension System during and after the green revolution. The technological innovation evolved as a result of enhanced resource allocations to agricultural research and extension (R&E), together with favourable policy support. These have improved agricultural performance and thereby helped to alleviate poverty in the country (Evenson and Jha, 1973; Evenson and McKinsey, 1991; Rosegrant and Evenson, 1992; Kumar and Rosegrant, 1994, Pal and Singh, 1997). These studies have highlighted the role of agricultural R&E investment in improving the total factor productivity (TFP) of the agricultural sector, with impressive rates of return therein. The returns on investments in agricultural research have been estimated to be as high as 33 per cent (Chand *et al*, 2011). Some studies (such as Fan *et al*, 1999) have reported that expenditure on agricultural R&E in India is much more effective in reducing poverty and accelerating growth than most alternatives.

Investment in agricultural R&E is mainly undertaken by the public sector in India, though the private sector has also started getting involved in recent years. The national agricultural research system (NARS) in the country comprises a strong network of over one hundred research institutions, under the aegis of the Indian Council of Agricultural Research (ICAR), and about 50 state agricultural universities (SAUs) spread across the country. In addition, a number of commodity boards and non-agricultural research universities and scientific organizations supplement agricultural research. The grassroots-level agricultural extension service is mainly controlled by the state departments of agriculture, through a network of village-level extension centres attached to the Directorate of Extension. In addition, a network of Krishi Vigyan Kendras (KVKs) managed by ICAR institutes, SAUs and other non-governmental organizations (NGOs) also undertake frontline extension services, with the prime aim of improving the technical literacy of farmers.

The public funding in agricultural R&E essentially involves strengthening the NARS in terms of size, coverage, quality and intensity of efforts. Though several past studies have empirically shown that investment in agricultural R&E is associated with high internal rates of return, its present level is not felt to be commensurate with what's needed for consistent growth in the sector. As of TE 2010, the share of expenditure in agricultural research and education, in total agricultural GDP, was 0.66 per cent, and that of agricultural extension and training was only 0.18 per cent. During the 12th Five Year Plan (2012–2017), the government aims to raise research investment to 1 per cent of agricultural GDP to achieve four per cent agricultural growth. However, recent studies (Beintema and Stads, 2008; Mruthyunjaya and Kumar, 2009) suggest that even this level of investment would not be sufficient to achieve the growth target in the sector, in the face of a variety of emerging challenges such as a shrinking natural resource base, climate change and slowdown in TFP growth.

Against this backdrop, it is interesting to examine how far the attempts to strengthen the R&E system in the country have been successful in the recent past. Important questions to be answered are: Has the contribution of state governments to agricultural R&E investments been on the decline, as noted by past studies? How does agricultural R&E funding differ temporally and spatially across the country? What is the present rate of returns on investments of R&E spending in agriculture? Is the long-standing argument for increasing the share of R&E expenditure in total allocations to the sector justified? This paper analyses different dimensions of investment in agricultural R&E and their relationship to agricultural productivity. The specific objectives of the paper are to track past patterns of public spending on R&D to see whether they have been sufficient; to explore variation in public spending on R&D across states; to estimate the returns to R&D spending; and to test whether states that spend more achieve higher TFP growth.

The Data and Methodology

The data on public R&E expenditure covering a time span of 50 years from 1960 to 2010 were obtained from 'Combined Finance and Revenue Accounts of the Union and State Governments in India', published by the Office of the Comptroller and Auditor General of India. This source provides expenditure data pertaining to agricultural R&E under two separate sub-heads, namely, agricultural research and education, and extension and training. The term 'R&E investment' in this paper refers to the combined expenditure on these two sub-heads. However, the above R&E data does not include expenditures made by the private sector in this field. It should also be noted that the expenditures on agricultural research outside the Minsitry of Agriculture, such as those allocated by the Department of Science and Technology and Department of Biotechnology, are also not covered in the study. The money spent by NGOs and other private organizations on various extension services also does not appear in the above R&E data.

Notwithstanding the above limitations, the public R&E data used in the analysis pertain to the major component of all expenditures on R&E in India. The analysis covered the major sub-sectors of agriculture, that is, crops, livestock, fisheries, and soil and water conservation. The time series on the GDP deflator,[1] with 2004–2005 as the base year, was used to deflate the R&E series to enable temporal comparisons. The intensity in R&E investment was determined by obtaining the corresponding expenditure per hectare as well as per thousand people in different states. The share of R&E investment in GDP agriculture was computed state-wise across different years to explain the relative importance accorded to the sector in total resource allocation. The relative contributions of central and state governments to total R&E investment in the agricultural sector were also worked out. The TFP index of the crop sector in various states was worked out using the Divisia-Tornqvist index (presented in Appendix B) and its respective growth rates and share in total ouput growth were drawn to enable further analysis on returns to research investment. The data used in TFP estimation was drawn from 'Cost of Cultivation Scheme' data of major crops published by the Department of Agriculture, Government of India (for further details on methodological aspects related to TFP estimation, see Rosegrant and Evenson (1992) and Chand *et al* (2011).

Returns to Research Investment

We estimated the value of marginal product (VMP) of research and extension stock (R) by using the elasticity of TFP with respect to research and extension stock, as:

$$\mathrm{VMP}(R) = b\left(\frac{V}{R}\right)$$

Where R is the R&E stock,[2] V is the value of output for the crop sector associated with TFP and b is the TFP elasticitiy of R&E stock estimated by Fan *et al* (1999) using the TFP determinants equation.[3] The benefit stream is generated under the assumption that the benefit of R&E investment made in period *t-i* will start generating benefits after a gestation period of 5 years, will do so at an increasing rate in the next 9 years, will remain constant in the next 9 years and thereafter will start declining. Using weights on time,[4] as suggested by Evenson and Pray (1991) and Evenson *et al* (1999), the investment of one rupee in year *t-i* will generate a benefit equal to 0.1*VMP in year *t-i*+6, 0.2*VMP in year *t-i*+7 and so on, and it will be 0.9*VMP in year *t-i*+14. After this the benefit will be equal to VMP up to the year *t-i*+23. Then the benefit for year *t-i*+24 onwards will be equal to 0.9 *VMP and in year *t-i*+25 will be 0.8*VMP 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*' is considered as the marginal internal rate of return to public R&E investment.

Results and Discussion

Trends in Research and Extension Investments

The onset of the green revolution in India underscored the need for investment in key areas such as irrigation and water management, agricultural inputs (improved seeds, fertilizers and plant protection chemicals), agricultural credit and storage infrastructure. However, the real impetus for the green revolution came from the adoption of high-yielding varieties of major crops, which were initially sourced from outside the country. Later these were successively developed indigenously; this became possible with considerable investment in Indian agricultural research. An efficient research infrastructure, together with the development of a strong extension system, spread the green revolution to a considerable part of the country within a short span of time. With the growing awareness of the importance of R&E for increasing agricultural productivity, successive governments accorded increasing priority to this sub-sector. Thus, investments in India's agricultural R&E exhibited a growing trend over the years. The R&E investments increased not only in absolute terms, but also in terms of their share in agricultural GDP. The investment in agricultural research, which had a share of 0.30 per cent of total GDP in agriculture in 1980–1981, improved considerably to reach 0.52 per cent in 1990–1991, and 0.77 per cent in 2010–2011 (Figure 1). On the other hand, the share of investment in extension services increased modestly, from 0.12 per cent in 1980–1981 to 0.18 per cent in 1990–1991, and stood within that range in the successive years. Figure 1 shows that a brief downturn in R&E investment occurred during the 1990s because of the changes in policy priorities after economic reforms. However, the share has increased impressively during the last decade, though with occasional troughs and peaks. The Government of India aims to increase investment in this key sector in its forthcoming plan to reap higher agricultural growth even amid scores of emerging constraints and challenges. A similar picture of R&E investments as a share of GSDP (gross state domestic product) in different Indian states is provided in Appendix A. A general upward trend in R&E allocation over the past three decades was observed for almost all states. The share stood at less than 1 per cent in most states, but certain states (such as Himachal Pradesh, Jammu and Kashmir, Kerala, Maharashtra and Tamil Nadu) allocated a share above 1 per cent of their GSDP to R&E investment.

The 10-year averages of India’s R&E investments, along with annual growth rates and relative shares of allocation for the period 1960–2010, are presented in Table 1. The investments in both

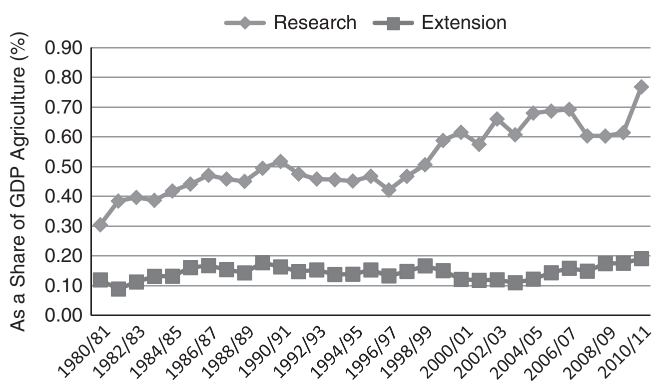

Figure 1: Investment in agricultural research and extension as a share of GDP (agriculture).
Source: Computed by authors based on data from CAG, 2013; MOSPI, 2013.

Table 1: Average annual investment in agricultural research and extension in India: 1961–2010

Period	*Investment (in million rupees at 2004–2005 prices)*		*Share of total R&E investment (%)*		*Annual growth (%)*	
	Research	*Extension*	*Research*	*Extension*	*Research*	*Extension*
1961–1970	4410.6	2303.7	64.95	35.05	3.2	7.2
1971–1980	6721.5	2266.0	77.51	22.49	8.1	−2.2
1981–1990	13536.0	4401.6	75.23	24.77	6.5	9.3
1991–2000	20645.4	6046.1	77.71	22.29	6.1	2.7
2001–2010	33903.9	7730.5	81.43	18.57	3.8	9.1

Source: Computed by authors based on data from CAG, 2013.

Table 2: Relative shares of central and state government investments in agricultural R&E from 1961 to 2010

Source	*Period*	*Investment (in million rupees at 2004–2005 prices)*		*Shares (%)*	
		Research	*Extension*	*Research*	*Extension*
All state governments	1961–1970	3914.7	2296.3	90.7	99.8
	1971–1980	4525.3	2161.0	59.2	95.1
	1981–1990	7441.4	4137.4	55.3	94.1
	1991–2000	11299.4	5646.7	53.9	93.3
	2001–2010	15754.6	6185.8	46.6	79.1
Central government	1961–1970	495.9	7.4	9.3	0.2
	1971–1980	2958.0	105.0	40.8	4.9
	1981–1990	6094.5	264.2	44.7	5.9
	1991–2000	9346.0	399.5	46.1	6.7
	2001–2010	18149.4	1544.6	53.4	20.9

Source: Computed by authors based on data from CAG, 2013.

research and extension were found to grow steadily over the years. The research investment grew at an annual rate of 3.2 per cent in the decade 1961–1970, whereas extension investment grew at 7.2 per cent per annum. The growth in research investment picked up over the next two decades, with annual growth rates of 8.1 and 6.5 per cent per year, respectively, during 1971–1980 and 1981–1990. However, in the case of investment in extension, a deceleration (−2.2 per cent) was observed during 1971–1980, followed by a recovery with 9.3 per cent annual growth in the subsequent decade. Though investment in extension maintained its growth in the recent period (9.1 per cent during 2001–2010), a slowdown has been observed for research investment (3.8 per cent) during the decade of 2001–2010, which is a matter of concern. In terms of relative shares, research has received a higher allocation throughout the past four decades. The share of research in total R&E investment ranged from 65 to 82 per cent during the period. On the other hand, the share of extension in total investment declined from 35 per cent in 1961–1970 to 18 per cent in 2001–2010. This shows that spending on extension is not commensurate with spending on research over time. This has significant policy implications, as lower relative allocations to extension could retard the flow of new knowledge from lab to land, and the gains accrued from higher research investment could be underutilized.

The share of states in total R&E expenditure was as high as 91 per cent in research and 99 per cent in extension during the period 1961–1970, but it reduced consistently over the years and was 46.6 per cent in research and 79.1 per cent in extension during 2001–2010 (Table 2). A closer

Table 3: Structural changes in research and extension investment by agricultural sub-sectors, India

Government	*Period*	*Agriculture (crop)*	*Livestock*	*Fisheries*	*Soil and water Conservation*
Per cent share of total research investment					
All States	1961–1970	68.19	25.67	3.27	2.86
	1971–1980	71.09	23.46	3.22	2.23
	1981–1990	73.32	21.95	2.79	1.94
	1991–2000	77.74	18.31	2.66	1.29
	2001–2010	80.77	14.15	2.15	2.92
Central	1961–1970	96.26	2.49	0.50	0.75
	1971–1980	96.63	2.59	0.33	0.44
	1981–1990	95.53	3.90	0.24	0.33
	1991–2000	86.83	8.22	4.04	0.91
	2001–2010	74.88	10.21	6.05	8.86
India (states+centre)	1961–1970	72.21	21.86	2.67	3.25
	1971–1980	73.95	21.21	2.49	2.35
	1981–1990	73.96	21.95	2.44	1.66
	1991–2000	79.20	16.00	3.52	1.28
	2001–2010	78.66	11.38	4.15	5.81
Per cent share of total extension investment					
All States	1961–1970	84.93	6.71	5.66	2.70
	1971–1980	86.23	6.74	4.26	2.76
	1981–1990	86.93	7.40	3.19	2.48
	1991–2000	90.79	3.93	2.56	2.72
	2001–2010	88.66	7.13	2.42	1.79
Central	1961–1970	85.00	0.10	10.10	4.80
	1971–1980	85.00	0.10	10.10	4.80
	1981–1990	85.00	0.10	10.10	4.80
	1991–2000	71.00	0.18	18.08	10.75
	2001–2010	93.15	0.04	5.38	1.43
India (states+centre)	1961–1970	88.35	5.06	3.70	2.89
	1971–1980	88.35	5.06	3.70	2.89
	1981–1990	88.35	5.06	3.70	2.89
	1991–2000	89.54	3.38	3.76	3.32
	2001–2010	89.74	5.83	3.02	1.42

Source: Computed by authors based on data from CAG, 2013.

look at the changes in the relative shares reveals that the role of the central government in funding research and extension expanded consistently, mainly because of the upscaling of such activities under the ICAR and other related centrally funded research institutes. In the case of extension, though the states dominate even now, the greater role assumed by the Directorate of Extension and strengthening of the KVKs have resulted in higher central government participation in allocation of resources.

During the past five decades, significant structural changes have occurred in the pattern of R&E spending in India. The relative priority accorded to various sub-sectors of agricultural and allied sectors has shifted considerably over time. In successive decades, the priority of the crop sector in research spending has increased, whereas that of the livestock sector has declined. The average share of research spending on crops during 1961–1970 was nearly 72 per cent, which improved to 79 per cent in the decade 2001–2010 (Table 3). On the other hand, the research share of the livestock sector decreased from 26 to 14 per cent during this period. This reflects the pro-crop bias in R&E spending, which increased over time due to various reasons. Following the introduction of green revolution technologies in the late 1960s (that heavily favoured the staple crops rice and wheat), the focus of research spending in India revolved mostly around these two crops in the ensuing years. Though the 1980s and 1990s witnessed diversification of the agricultural production base, this was more in terms of spending on other marginal crops such as pulses and oil seeds. Though spending on the livestock and fishery sectors picked up in absolute terms, it was not sufficient to make a major dent in the aggragate pattern of investments. Moreover, the research establishments in the country such as the ICAR and agricultural universities also did not deviate much from their previous trajectory, thereby resulting in the relative neglect of the livestock sector in terms of research allocations.

However, despite low investment in the past, Indian livestock productivity remained high and could meet the growing demand for livestock and its products, thereby prompting the policy makers not to give priority to increase investments in this sector (Birthal *et al*, 2002; Kumar *et al*, 2013). However, the share of expenditure on the fisheries sector improved slightly, and that of soil and water conservation dwindled in the range of 1–6 per cent during the period under study. Though the above trend existed at the aggregate level, disparate trends were observed in the investments made by the central and state governments. The allocation by states followed an overall trend in which the share of crops improved and of livestock and fisheries declined, but in the case of central government funding, an opposite trend was observed. More than 95 per cent of central funding was for the crop sector in the first three decades, and it experienced a drastic shift in the following decades. By the period 2001–2010, only 75 per cent of central funding was for crops, while nearly 10 per cent was allocated to livestock, and the rest was shared between fisheries and soil and water conservation. The investment in extension, however, did not experience much of a structural change. The shares of crops in total extension investment hovered around 88–90 per cent, and those of livestock, fisheries, and soil and water conservation ranged between 3–5, 3–4 and 1–4 per cent, respectively, during the past five decades.

Intensity of R&E Investments

The intensity of investment, which is a better measure than absolute values to judge the relative distribution of R&E investments across states, was computed by dividing the total investment per unit of cropped area and per unit of population. To calculate this, the R&E investments for all major Indian states for the period 2001–2010 were computed, and are presented along with their respective growth rates in Table 4. A cursory glance at the results reveals the existence of high interstate variations in R&E investments. The states leading in terms of per hectare investment intensity were Himachal Pradesh, Jammu and Kashmir, Kerala, Tamil Nadu and Haryana. These states were also the highest in terms of R&E investment per thousand populations, albeit in a different order. However, in leading agricultural states such as Punjab, Maharashtra and Gujarat, the investment intensity was modest. The states[5] that fared poorly in this classification (particularly in terms of R&E intensity per thousand people) were Bihar, Madhya Pradesh, Rajasthan, Odisha, Uttar Pradesh and West Bengal. Moreover, as evident from the growth estimates, the investment intensity showed a declining trend in these states, which – if unchecked – will have debilitating impacts on their agricultural productivity in the future.

Returns on Investment in R&E

While the level of R&E investments and their intensity is a crucial factor that determines the agricultural productivity of states, and for that matter of the country as a whole, the actual returns on investment depend considerably on the TFP and its growth. TFP growth is determined by factors such as research and extension stock created over the years, infrastructure and the quality of natural resources. To estimate marginal value product and internal rates of return (IRR) on

Table 4: Research and extension investment intensity by state in India, 2001–10

State	*Per ha. of net cropped area*		*Per thousand people*	
	Rupees at 2004–2005 prices	*Growth (%)*	*Rupees at 2004–2005 prices*	*Growth (%)*
Andhra Pradesh	183.53	5.57	22.70	4.24
Assam	360.64	5.25	31.90	3.68
Bihar[a]	184.29	2.73	7.86	−4.35
Gujarat	167.94	2.59	26.89	0.94
Haryana	450.77	8.77	63.04	6.74
Himachal Pradesh	1060.04	4.88	84.19	3.29
Karnataka	142.55	4.72	23.81	2.89
Kerala	519.33	2.90	33.57	1.99
Madhya Pradesh[a]	30.04	2.46	6.00	−2.44
Maharashtra	172.53	1.72	26.94	0.03
Jammu & Kashmir	927.32	6.13	54.76	3.91
Odisha	58.11	1.90	7.97	−0.12
Punjab	222.07	3.08	33.74	1.74
Rajasthan	37.53	0.24	8.81	−1.84
Tamil Nadu	421.28	2.99	29.66	0.48
Uttar Pradesh[a]	73.90	−2.87	6.16	−5.44
West Bengal	140.59	3.36	8.27	1.92
India	297.12	4.69	34.40	2.84

[a]pertains to undivided Bihar, Madhya Pradesh and Uttar Pradesh.
Source: Computed by authors based on data from CAG, 2013; DES, 2013.

R&E investments, the total factor productivity growth of the crop sector for different states was computed for the period 1980–2008, and the results are presented in Table 5. The respective shares of TFP growth in the total output growth in the states were also obtained in order to understand the relative contribution of TFP growth to output growth. Wide variations existed in TFP growth across states. The states associated with high levels of TFP growth were Tamil Nadu (2.88 per cent), Gujarat (2.39 per cent), Odisha (1.87 per cent) and Madhya Pradesh (1.17 per cent) (Table 5). On the other hand, Bihar (0.19 per cent), Maharashtra (0.21 per cent), Himachal Pradesh (0.21 per cent), West Bengal (0.21 per cent), Assam (0.26 per cent) and Karnataka (0.37 per cent) exhibited low performance. The overall TFP growth for India was 1.09 per cent. The share of TFP in output growth also varied considerably across states, with high estimates for Tamil Nadu (80.2 per cent), Odisha (79.9 per cent), Gujarat (45.2 per cent) and Haryana (38.3 per cent). At the all-India level, the contribution of TFP to total agricultural output growth is estimated to be 29.1 per cent.

The VMP and IRR to R&E investments in different states of India were estimated based on the respective average 10-year R&E investment, the value of product of crops, the share of TFP growth in output growth, and TFP elasticity with respect to R&E investments (Table 6). As expected, the states with a higher share of TFP in output growth also performed better in terms of VMP and IRR. The VMP values ranged from less than one to nearly 40, whereas the range of IRR was 18 to 80 per cent (Table 6). The states with high VMP and high IRR included Madhya Pradesh, Odisha, Uttar Pradesh, Tamil Nadu, Punjab, Gujarat and Andhra Pradesh. On the other hand, poor returns on investment were exhibited by Himachal Pradesh, Maharashtra and Assam.

It is worth noting that, in spite of the high intensity of investments, Himachal Pradesh, Haryana and Assam have fared poorly in realizing higher levels of productivity. To make this point clearer, a scatter plot depicting different states in terms of their relative levels of investment intensity and VMP of R&E investment is presented in Figure 2. From this figure, we can infer that

Table 5: Total factor productivity growth in crop sector by state, 1980–2008

State	*Input growth (%)*	*Output growth (%)*	*TFP growth (%)*	*TFP share in output growth (%)*
Andhra Pradesh	1.49	2.17	0.69	31.10
Assam	1.18	1.44	0.26	18.07
Bihar[a]	0.80	0.99	0.19	18.57
Gujarat	2.76	5.15	2.39	45.19
Haryana	2.50	4.11	1.61	38.27
Himachal Pradesh	2.17	2.38	0.21	8.50
Karnataka	1.48	1.84	0.37	19.51
Madhya Pradesh[a]	3.21	4.37	1.17	26.69
Maharashtra	4.16	4.36	0.21	4.53
Odisha	0.47	2.35	1.87	79.86
Punjab	1.85	2.75	0.90	32.04
Rajasthan	3.50	4.24	0.74	17.41
Tamil Nadu	0.71	3.59	2.88	80.22
Uttar Pradesh[a]	1.48	2.23	0.75	32.98
West Bengal	2.03	2.25	0.21	9.23
All-India	2.66	3.75	1.09	29.01

[a]Pertains to undivided Bihar, Madhya Pradesh and Uttar Pradesh.
Note: Jammu and Kashmir and Kerala were dropped from the computations because of non-availability of data on certain parameters.
Source: Computed by authors based on data from DES, 2013.

Table 6: Estimated VMP and IRR to R&E investment in agricultural (crop) sector, India

State	*VMP of R&E investment*	*IRR (%) to investment in R&E*
Andhra Pradesh	9.56	51.83
Assam	2.64	32.54
Bihar[a]	5.84	43.74
Gujarat	9.77	52.22
Haryana	5.63	43.16
Himachal Pradesh	0.79	19.17
Karnataka	6.70	45.90
Madhya Pradesh[a]	37.86	80.27
Maharashtra	0.69	18.00
Odisha	38.34	80.58
Punjab	11.65	55.37
Rajasthan	8.62	50.06
Tamil Nadu	11.35	54.90
Uttar Pradesh[a]	24.12	69.94
West Bengal	5.54	42.91
All-India	8.17	49.14

[a]pertains to undivided Bihar, Madhya Pradesh and Uttar Pradesh.
Note: TFP elasticity with respect to R&E was assumed to be 0.296 (estimated by Fan *et al*, 1999)
Source: Computed by authors based on data from CAG, 2013.

Madhya Pradesh, Odisha and Uttar Pradesh fall in the category of low investment-high VMP, whereas Himachal Pradesh was notable because of its presence in the range of high investment-low VMP. In relative terms, most of the states fell in the category of low investment-low VMP,

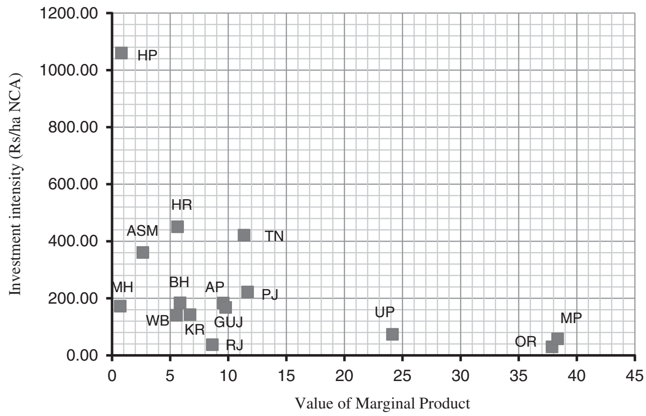

Figure 2: Distribution of states based on relative levels of VMP and intensity of R&E investments.
Note: AP: Andhra Pradesh, ASM: Assam, BH: Bihar, GUJ: Gujarat, HR: Haryana, HP: Himachal Pradesh, KR: Karnataka, MP: Madhya Pradesh, MH: Maharashtra, NCA: Net Cropped Area, OR: Odisha, PJ: Punjab, RJ: Rajasthan, UP: Uttar Pradeh, TN: Tamil Nadu and WB: Best Bengal
Source: Computed by authors based on data from CAG, 2013; DES, 2012.

and the notable ones were Maharashtra, West Bengal, Bihar and Karnataka. Therefore, the main factors should be identified that lead to such high levels of disparity in returns on R&E investment among the states, and what factors deter some states from achieving higher VMP and TFP growth despite the high intensity of R&E investment. Notwithstanding this, the observed general pattern prompts an inference that states making lower allocations to R&E achieve lower VMP and TFP growth in relative terms.

Conclusions

This paper has analyzed the spatial and temporal dimensions of agricultural R&E investments in India, with an attempt to draw linkages between investments and agricultural productivity. The R&E investments in Indian agriculture have grown consistently over the past five decades, both in absolute terms and as a share of GDP agriculture. Consequently, significant structural changes have occurred in their pattern mainly because of the shift in relative importance accorded to various sub-sectors across space and time. In terms of resource allocations to the agricultural sector, the research component has received higher attention as compared to the extension component, and the gap between the two appears to have widened over the years. Similarly, there has been a greater focus on the crop sub-sector than on the livestock sub-sector and this has precipitated over time, with the share of the former in total R&E expenditure increasing at the expense of the latter. The relative neglect of the livestock sector is a matter of concern and should be considered while making future allocations. However, the fisheries sub-sector has been receiving higher allocations in consecutive plan periods, whereas the share of soil and water conservation has remained volatile. Notably, the share of states in the aggregate R&E investments has declined over the years, while that of the centre has improved proportionately. Spatially, significant variations in investment intensity exist across states, with per hectare R&E investments differing by as much as 1:20 between the lowest-intensity and highest-intensity states.

Many states that fared low on investment intensity were also found to be backward in terms of agricultural productivity. The returns on R&E investment in various states, as well as all India, has been estimated with two common indicators, that is, VMP and IRR. With a high disparity in TFP in agriculture and its share in output growth, wide variations in VMP and IRR have been noted across states. While states such as Madhya Pradesh, Odisha, Uttar Pradesh and Tamil Nadu have fared better in terms of returns on investments, the low-performing states include Himachal Pradesh, Maharashtra and Assam. It has also been observed that high investment intensity does not necessarily result in high returns on investment. The states with higher share of TFP growth as a part of output growth performed better in terms of returns to investment. In general, the findings of the article suggest that a shift in focus from investment heads of low significance to the important head of agricultural R&E is necessary to meet the future growth challenges in the agriculture sector. The policy decisions therefore have to be fine-tuned towards this end so that growth in this sector is not compromised in the future.

Notes

1. Refers to the index used to deflate current price estimates of GDP to constant prices. This is a better index compared to the wholesale price index to deflate macro variables at the country/state level.
2. Research and extension stock were constructed from this expenditure data using 5-year lag structure for research and three years for extension. The research and extension stock variable was constructed by summing up research investment of 5 years and extension investment of 3 years. The stock was defined as one-fifth of the spending in the previous year, plus two-fifths of the spending 2 years before, before plus three-fifths of the spending 3 years before, plus four-fifths of the spending 4 years before, plus the sum of all spending 5 years before and earlier. These weights are admittedly arbitrary and chosen to reflect the lower impact of research activity in the earlier stages. The extension stock variable was constructed by summing up 3 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 $t-3$. These weights were chosen to reflect the higher impact of extension activity in the earlier stages (Evenson *et al*, 1999).
3. Only a single country-level elasticity of TFP with respect to R&E stock (estimated by Fan *et al*, 1999) was used in the analysis as state-specific elasticities were not available in the literature. This may be a limitation of the study as the underlying assumption is identical production functions across states.
4. We followed the 'inverted *V*' scheme for constructing the time weights. This scheme has three regions. The first, sloping upward, refers to the number of years between the first appearance of a research benefit and its full effect. During this time, the research outcome has an increasing impact. In this region of the *V*, research output (VMP) is multiplied by smaller fractions, while more distant results are multiplied by larger fractions, until at the top of the upward-sloping region, the weights become one. The second region, a horizontal plateau, refers to the number of years the research output can continue to make its full contribution. The weights remain equal to one here. The third region, sloping downward, represents a sort of decay of the contribution of the research. In this region, earlier research contributions are multiplied by weights that become successively smaller as time passes.
5. From here on, the results pertaining to Bihar, Madhya Pradesh and Uttar Pradesh correspond to the status before their bifurcations.

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Appendix A

Table A1: Share of investment in research and extension to agricultural GDP by state, India

State	*Period*	*Research*	*Extension*	*R&E*
Andhra Pradesh	1981–1990	0.16	0.05	0.21
	2001–2010	0.50	0.03	0.53
Assam	1981–1990	0.38	0.06	0.44
	2001–2010	0.55	0.24	0.79
Bihar	1981–1990	0.13	0.23	0.36
	2001–2010	0.38	0.30	0.68
Gujarat	1981–1990	0.26	0.04	0.30
	2001–2010	0.65	0.20	0.85
Haryana	1981–1990	0.21	0.07	0.29
	2001–2010	0.57	0.13	0.70
Himachal Pradesh	1981–1990	0.81	0.09	0.90
	2001–2010	1.64	0.35	1.99
Jammu & Kashmir	1991–2000	2.27	0.22	2.49
	2001–2010	0.39	0.43	0.83
Karnataka	1981–1990	0.22	0.02	0.24
	2001–2010	0.56	0.04	0.60
Kerala	1981–1990	0.23	0.05	0.28
	2001–2010	0.96	0.04	1.00
Madhya Pradesh	1981–1990	0.08	0.03	0.10
	2001–2010	0.27	0.04	0.31
Maharashtra	1981–1990	0.40	0.03	0.43
	2001–2010	0.78	0.20	0.98
Odisha	1981–1990	0.12	0.04	0.16
	2001–2010	0.26	0.08	0.35
Punjab	1981–1990	0.30	0.06	0.36
	2001–2010	0.51	0.01	0.53
Rajasthan	1981–1990	0.14	0.07	0.22
	2001–2010	0.34	0.06	0.40
Tamil Nadu	1981–1990	0.25	0.13	0.38
	2001–2010	0.74	0.48	1.21
Uttar Pradesh	1981–1990	0.15	0.01	0.16
	2001–2010	0.29	0.16	0.45
West Bengal	1981–1990	0.18	0.05	0.23
	2001–2010	0.23	0.11	0.34

Source: Computed by authors based on data from CAG, 2013.

Appendix B

Divisia-Tornqvist index for computing TFP

TFP measures the amount of increase in the total output, which is not accounted for by increases in the total inputs. It is defined as the ratio of an index of aggregate output to an index of aggregate input. One of the most defensible methods of aggregation in productivity measurement is Divisia aggregation. 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). The following formulae were used for constructing the indices:

Total output index (TOI)

$$TOI_t/TOI_{t\text{-}1} = \prod_j (Q_{jt}/Q_{jt\text{-}1})^{(R_{jt}R_{jt\text{-}1})^1/2}$$

Total input index (TII)

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

where,

R_{jt} is the share of jth crop output in total revenue in year t,
Q_{jt} is the output of jth 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.

For the productivity measurement over a long period of time, chaining indexes for successive time periods is preferable. With Chain-linking, an index is calculated for two successive periods t and t-1, over the whole period t_0 to T, (sample from time t=0 to t=T) and the separate indexes are then multiplied together:

$$\mathrm{TOI}(t) = \mathrm{TOI}(1).\mathrm{TOI}(2) \ldots \ldots \ldots \ldots \ldots \ldots \mathrm{TOI}(t-1).$$

$$\mathrm{TII}(t) = \mathrm{TII}(1).\mathrm{TII}(2) \ldots \ldots \ldots \ldots \ldots \ldots \mathrm{TII}(t-1).$$

Total factor productivity index (TFP)

$$\mathrm{TFP}_t = (\mathrm{TOI}_t/\mathrm{TII}_t)$$

Chain-linking index takes into account the changes in relative values/costs throughout the period of the study. This procedure has the advantage that no single period plays a dominant role in determining share weights and biases are likely to be reduced. The above equations provide the indices of total output, total input, and TFP indices for the specified time 't'.