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A Novel Adoption Index of Selected Agricultural Technologies: Linkages with Infrastructure and Productivity

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Abstract

Variations in agricultural productivity in different states across the country are mainly due to large differences in the level of adoption of selected agricultural technologies and the underlying determinants of adoption of these technologies. Agricultural technologies selected in this paper include high-yielding varieties of seeds, chemical fertilizers, pesticides, use of machinery, etc. The pattern of adoption has been examined across the country based on the 54[th] round of NSSO dataset. The quantification of adoption has been carried out for each state in the form of a novel 'adoption index'. The relation between adoption index and status of the infrastructure in the corresponding state has been examined. The strong correlation between adoption index and composite index of infrastructure and development has emphasized the need for improving infrastructure to increase adoption of improved agricultural technologies, which would increase the value of per hectare crop productivity. The functional analysis has revealed that infrastructures like electricity, irrigation, credit and extension organizations positively influence the adoption of the improved technologies. The study has suggested that there is a need to formulate policies which would help increase the availability of electricity, irrigation and institutional credit and improve the access to the extension organizations for the adoption of improved agricultural technologies and enhancement in productivity.

Introduction

Agricultural productivity and performance show wide variations across different regions of the country (Chand, 2008). It shows significant potential in raising the agricultural production by addressing the factors related to differences in performance. The variation is mainly due to large differences in not only level of adoption of latest agricultural technologies but also the underlying determinants, which could be influenced through appropriate policies. The Eleventh Plan draft shows serious concerns towards reducing rural-urban divide to achieve the goal of inclusive growth. Further, meeting food and nutritional requirements of the growing population are possible only if the rate of agricultural development is accelerated through adoption of improved agricultural technologies and formulating policies favouring appropriate institutional and infrastructural changes.

Agricultural technologies include all kinds of improved techniques and practices which affect the growth of agricultural output. Due to data limitations, only five agricultural technologies have been used in this study for developing a new adoption index. These include (a) high-yielding varieties of seeds, (b) chemical fertilizers, (c) pesticides, (d) weedicides, and (e) use of machinery, etc. By virtue of improved input/output relationships, new technology tends to raise output and reduces average cost of production, which in turn results in substantial gains in farm income. Adopters of improved technologies increase their productions, leading to

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constant socio-economic development. On the other hand, non-adopters can hardly maintain their marginal livelihood with socio-economic stagnation leading to deprivation.

There is a plethora of studies related to adoption of different agricultural technologies but these are crop-specific, input-specific or location-specific (Singh, 1993). Studies by Feder *et al.* (1985) provide a comprehensive survey of adoption studies in developing countries. They have concluded that most adoption studies view the adoption decision in dichotomous terms, but there is a need for the adoption study covering the intensity of use, e.g. how much area is under high-yielding varieties (HYVs). They supported the need for proper accounting of varied range of responses employing suitable statistical techniques. A recent study by Bhalla (2006) has brought out adoption of improved seeds, fertilizers, manures, pesticides and veterinary services on the basis of dichotomous response of farmers. The dichotomous response reflects the status of awareness of improved technology rather than the actual adoption. There is hardly any study available in the literature for the country which estimates level of adoption for the entire crop sector by a farm household.

This paper has studied the pattern of adoption of agricultural technology based on total agricultural activities of a household in different states across the country. A comparison has been attempted at the state level. The quantification of adoption of technologies has been done for each state in the form of a new 'adoption index'. It is envisaged that such adoption goes hand in hand with infrastructural and developmental activities. The relation between adoption index and each of the expected infrastructural and developmental parameters has also been studied. Further, a composite index of infrastructure has been developed and the relation between adoption index and composite index of infrastructure and development has been explored. To study the association of adoption of improved cultivation practices and productivity, a correlation between adoption index and agricultural productivity (Rs/ha of NSA) has been used. Significant determinants having potential to promote the level of adoption have been identified. These would lead to increase in productivity. The study has been undertaken with the following objectives:

- To develop state-wise adoption index for selected agricultural technologies in the country,
- To analyze the relation between the state-wise adoption index and the state-wise agricultural productivity,
- To identify the significant infrastructural parameters and to estimate the relationship between infrastructural index and adoption index, and
- To study the effect of variations in infrastructural parameters and other important factors on the adoption of selected agricultural technologies in the country.

Data and Methodology

In India, the on-going technological change in agriculture was initiated during the 1960s when the government introduced and disseminated in certain regions of the country the HYVs of wheat and rice. The adoption of this technology has been accompanied by a marked increase in the use of improved seeds, fertilizers, pesticides and irrigation and mechanisation of agriculture throughout the country. Though the available macro-level data on the consumption of fertilizers and pesticides, irrigated area and area under improved varieties of the main cereal crops like wheat, rice, maize, jowar and bajra do provide some of the geographical spread, the data on the level of adoption of improved technology on farms or those on area treated with fertilizers or pesticides or tilled by tractors and power tillers remained virtually missing.

It was in the year 1998 that National Sample Survey Organization (NSSO) in its 54th round collected information regarding farm mechanisation and use of the improved 'seed-fertilizer-water' technology at the household level. The enquiry has, however, been confined to the study of field-crop cultivation. The data were collected from a sample of households by interview method. The survey period for the 54th round was January to June 1998 (NSSO, 1998). The data were based mainly on the information on cultivation practices collected in a part of Schedule 31of 54th round of NSSO.

In the 59th survey round of NSSO (Situational Assessment Survey of Farmers, January-June 2003), binary responses of farm households were compiled. However, knowing that a farmer is using HYVs, fertilizers and plant protection chemicals may not provide much information, because he may be using them for 1 per cent or 100 per cent of his acreage (Feder *et al.*, 1985). Indeed, on the basis of a comprehensive review of adoption studies, Schutjer and Van der Veen (1977) have concluded that the major technology issues relate to the extent and intensity of use at the individual farm level rather than to the initial decision to adopt a new practice. Using the evaluation of previous adoption work and new directions for empirical research by Feder *et al.* (1985), we have observed that the 59th survey round brings forward the status of awareness of modern and improved practices rather than exhibiting the status of intensity of adoption. Hence, the NSSO survey data for the year 2003 was not considered appropriate for computing the index of adoption and study the relation between adoption index and productivity. The extent of adoption of new technologies in agriculture can mainly be determined by the area under improved varieties and use of various inputs like fertilizers, seeds, plant protection chemicals and tractors (Table 1). The area under these inputs was available only in the 54th round of NSSO, hence for this study, data from the 54th round were used rather than of 59th round of NSSO.

It was hypothesized that technology adoption is a function of infrastructural and developmental parameters. To study the relation between infrastructural status and adoption, the parameters shown in Table 2 were considered important. It was hypothesized that irrigation facilities, extension organizations, roads, postal and telegraphic facilities, markets, credit, electricity and wages will have positive impact on the adoption, while poverty would hinder the adoption of improved agricultural technologies, which in turn, would lead to more poverty because of lower production.

Measurement of Adoption of Agricultural Technologies

Adoption of a single technology without considering other technologies can be measured by the proportion of the cropped area applied with that technology (Feder *et al.*, 1985). On the other hand, intensity of adoption can be measured by the application of improved inputs, and practices per unit of cropped area. But, whenever there is a blend of many technologies, the measuring of adoption of these agricultural technologies becomes a complex exercise. In this paper, the adoption of improved cultivation practices has been measured by development of a composite index.

Method of Index Development

Adoption Index (AI) is an aggregation of adoption of different dimensions of agricultural technology. The index was constructed for each state based on household data available in the NSSO Report No. 451, 'Cultivation Practices in India'. This state-wise adoption index was helpful in the identification of the problematic states that required intervention to change the pattern of adoption. Further, it can also help in identifying the model state for setting the targets while planning for future growth and development. Two methods for index development have been explored for measuring the extent of adoption. The first method

Table 1. Different parameters for adoption of agricultural technologies

Parameter	Identification
Percentage of gross cropped area under improved seeds	Seed
Percentage of gross cropped area applied fertilizers	Fert
Percentage of gross cropped area applied pesticides	Pest
Percentage of gross cropped area applied weedicides	Weed
Percentage of gross cropped area tilled by tractors	Tract
Source: NSSO, 54th round	

Note: All parameters are assumed to carry equal weight

Table 2. Infrastructural and developmental parameters considered for technology adoption

Parameter	Unit	Source	Identification
Per cent rural literacy	No.	National Human Development Report 2001, Planning Commission	Literacy
Average agricultural wages per day	Rs	Minimum Wages in India 2000, Ministry of Labour, Govt. of India	Wages
Per cent people below poverty line	No.	http://www.indiastat.com	BPL
Per cent villages connected with roads	No.	http://www.indiastat.com	Road
Per cent villages connected with P&T facility	No.	Census of India 1991	PT
Per cent gross cropped area under irrigation	No.	Statistical Abstract of Punjab 2002, Govt. of Punjab	Irrigation
Agricultural and extension organizations (SAUs, ICAR, NGOs, public sector undertakings, state government, Central Universities and KVKs) per ten thousand hectares of net sown area (NSA)	No.	http://www.indiastat.com	Organizations
Credit per hectare of net sown area	Rs/ha	Reserve Bank of India	Credit
Agricultural markets per thousand hectares of geographical area	No.	Rural Development Statistics 2002-03, National Institute of Rural Development	Markets
Electricity consumption per hectare of NSA	kWh	CMIE Indian Harvest compact disk	Electricity

Note: All the parameters were assumed to carry equal weights

$$I1 = \frac{C_i}{C} \qquad C \ge \max_i (C_i) \qquad \sum_{i=1}^{n}$$

called Index1 (I1) was based on statistical background developed by Narain *et al.* (1991). A set of n points represented the states (1, 2,…,n) for a group of indicators (1,2,…,k). It was represented by a matrix $[X_{ij}]$; i = 1, 2,…,n and j = 1, 2,…,k. As the indicators were normally in different units of measurement and the objective was to compute the single composite index relating to dimension in question, there was a need of standardization of these indicators. The indicators were standardized as shown below:

$$Z_{ij} = \frac{X_{ij} - \bar{X}_j}{s_j} \qquad \text{...(1)}$$

where,

$$\bar{X}_j = \sum_{i=1}^{n} \frac{X_{ij}}{n} \text{ for } (i = 1,2,\ldots,n) \text{ and } (j=1,2,...,k)$$

Then $[Z_{ij}]$ was presumed to denote the matrix of standardized indicators. The best state for each indicator (with maximum or minimum standardized value, depending on the direction of indicator) was identified and from this the deviations in the value for each state were taken for all the indicators in the following manner:

$$C_i = \left\{ \sum_{j=1}^{k} (Z_{ij} - Z_{oj})^2 \right\}^{1/2} \qquad \text{...(2)}$$

where, Z_{oj} was the standardized value of the j^{th} indicator of the best state and C_i denoted the pattern of adoption of the i^{th} state. The pattern of adoption was useful in identifying the states that could serve as a 'model' and it also helped in fixing the potential target of each indicator for a given state. The composite index (I1) was finally obtained using formula (3):

...(3)

where, C = $\bar{C}$ + λs ;

$\lambda \in Integer$ such that , $\bar{C} = \sum_{i=1}^{n} \frac{C_i}{n}$

and

$$s = \left\{ \sum_{i=1}^{n} \frac{(C_i - \bar{C})^2}{n} \right\}^{1/2} \quad ...(4)$$

For all practical purposes, $\lambda=2$ or $\lambda=3$ was used depending on the presence of extreme values of indicator in the data. The value of status index was non-negative and lied between 0 and 1. The value of index closer to zero indicated the lower level of adoption, while that closer to 1 indicated the higher level of adoption. The approach was used by Narain *et al.* (1991) for measuring the development level of the states. However, no work pertaining to development of adoption index has been reported to the best of our knowledge. The adoption index developed following this methodology has been referred to as AI1 in the paper.

The second method for computing composite index called *Index 2 (I2)* was based on the traditional method of computing the index for each indicator or dimension (Anonymous, 2006). Conventionally, index for any dimension is computed using the formula (5):

$$Dimension\ \ Index = \frac{Actual\ \ Value - Minimum\ \ Value}{Maximum\ \ Value - Minimum\ \ Value} \quad ...(5)$$

Following this, a composite index was developed by computing the weighted average. It was persumed that D_{ij} represented the value of the dimension index for the j^{th} state of the i^{th} indicator, then one gets Equation (6):

$$I2_j = \sum_{i=1}^{n} w_i D_{ij} \quad ...(6)$$

where, $I2_j$ is the composite index for the j^{th} state, and

w_i is the weight assigned to the i^{th} indicator (For equal weights, $w_i = 1/n$) and

$$D_{ij} = \frac{X_{ij} - Min(X_i)}{Max(X_i) - Min(X_i)} \quad ...(7)$$

This method (I2) suffered from the limitation that it was deeply affected by extreme values. On the other hand, the method I1 was least affected by addition or removal of extreme values because it has used standard deviation (mean+ë s.d.) rather than a range (Max-Min).

In this paper, indices were computed by both the methods (I1 as well as I2) for the purpose of comparison. The following status indices were obtained using above methods:

(i) Agricultural Technology Adoption Index, and

(ii) Infrastructure Index.

The computed adoption indices have been referred to as AI1 (Index 1 method), AI2 (Index 2 method), while infrastructure status indices have been referred to as II1 and II2.

Results and Discussion

Adoption Index and Productivity

Adoption indices for different states were computed using the dataset presented in Table 3. The data pertained to per cent gross cropped area under improved seeds, fertilizer, pesticides, weedicides and tractor cultivation for five major crops in 17 major states. These five major crops included crops from horticultural sector, plantation crops and other crops. The productivity referred to the crop output in Rs/ha of NSA.

Both the adoption indices were positively correlated (r = 0.986) and were significant. The state of Punjab ranked first with adoption index of 1, followed by Haryana with adoption index of around 0.8, using each of the index computation method. The states of Assam, Himachal Pradesh, Orissa and Kerala were observed to be at the bottom with adoption indices ranging from 0.1 to 0.2. Adoption indices (AI*1 and AI*2) were recomputed by excluding the states in the hilly regions (HP, J&K) and the state of Kerala, where agriculture is dominated by plantation crops.

As a first step, Kerala was excluded as this state has a totally different type of agricultural and cultivation practices. Since it is dominated by plantation crops, farmers in Kerala would not use seeds and tractors the way these are used in other states. Exclusion of Kerala from the major states improved the correlation by more than double.

Table 3. Per cent gross cropped area under improved practices and computed adoption indices and their comparison

States	Area (%) coverage under					Adoption Indices				Productivity
	Impro-ved seed	Ferti-lizer	Pesti-cide	Weed	Tractor use	AI1	AI2	AI*1	AI*2	(1997-98) Rs/ha (NSA)
Andhra Pradesh	65	94	22	82	51	0.551	0.623	0.543	0.602	25475
Assam	43	48	13	30	11	0.150	0.097	0.118	0.035	26777
Bihar	49	84	18	48	48	0.419	0.411	0.393	0.362	27324
Gujarat	84	95	31	76	67	0.653	0.746	0.653	0.737	18127
Haryana	78	89	61	59	94	0.781	0.801	0.771	0.781	35121
Himachal Pradesh	32	77	8	15	15	0.172	0.123	*	*	41434
Jammu & Kashmir	66	92	21	32	36	0.431	0.445	*	*	40774
Karnataka	65	82	23	55	27	0.453	0.449	0.437	0.415	20862
Kerala	37	67	14	38	15	0.235	0.183	*	*	59329
Madhya Pradesh	40	73	20	38	36	0.326	0.284	0.290	0.224	12421
Maharashtra	69	79	13	49	16	0.371	0.383	0.356	0.348	14056
Orissa	40	65	15	35	12	0.230	0.174	0.194	0.113	17539
Punjab	84	99	79	88	97	1	1	1	1	40950
Rajasthan	68	61	10	26	89	0.334	0.407	0.319	0.360	11775
Tamil Nadu	68	88	51	84	59	0.709	0.717	0.698	0.702	36041
Uttar Pradesh	52	92	17	28	76	0.419	0.462	0.390	0.405	28108
West Bengal	72	94	26	84	47	0.580	0.658	0.574	0.643	46385
r						0.168	0.117			

Notes: For the purpose of development of adoption index, all parameters were assumed to carry equal weights.
AI1 refers to the index computation using Narain *et al.*(1991)
AI2 is the index computation using the standard method
AI*1 is the index computation excluding the states of HP, JK and Kerala using Narain *et al*. (1991)
AI*2 is the index computation excluding the states of HP, JK and Kerala using standard method.
'*' refers to the states excluded for computation
r is the coefficient of correlation

Further, as the cultivation practices followed in the mountainous regions are different than of the plain regions, the correlation was established by excluding the states dominated by the hilly regions, viz. the states of Himachal Pradesh and Jammu and Kashmir. Correlation between adoption index and productivity of agricultural sector at the state level improved from 0.17 to 0.28 using AI1 and from 0.12 to 0.23 using AI2. Following this, the correlation was re-established by excluding the states of HP, J&K and Kerala simultaneously and the correlation significantly improved to 0.64 using AI1 and to 0.61 using AI2. Both these relations were significant at 5 per cent level. This empirical evidence clearly emphasizes the need for improving the adoption of technologies to improve productivity (Table 4).

To identify the factors that could be easily influenced and also had the potential to increase the adoption of agricultural technologies, it was essential to know the status of infrastructure at the state level and the relation between adoption index and infrastructural parameters.

Adoption Index and Infrastructural Parameters

Infrastructural parameters like irrigation, credit, power, marketing, roads, extension services and communication were considered important for the

Table 4. Correlation between adoption index and productivity

States	Correlation1	Correlation2	Correlation*1	Correlation*2
All 17 major states	0.17	0.12	*	*
All states except HP	0.26	0.21	*	*
All states except Kerala	0.39	0.36	*	*
All states except J&K	0.17	0.12	*	*
All states except HP, J&K	0.28	0.23	*	*
All states except HP, J&K, Kerala	0.64	0.61	0.63	0.61

Notes: Correlation1 is statewise correlation between AI1 and productivity (1997-98)
Correlation2 is statewise correlation between AI2 and productivity (1997-98)
Correlation*1 statewise correlation between AI*1 and productivity (1997-98)
Correlation*2 is statewise correlation between AI*2 and productivity (1997-98)
* denotes ' Not Applicable'

adoption of improved technology. The association of these parameters with the adoption index was analysed by studying the correlation between adoption indices and each of the individual factor (Table 5).

Irrigation has been observed as a major factor for promoting adoption. In the states of Punjab, Haryana and Uttar Pradesh, more than 70 per cent GCA was irrigated, while in a large number of states (Gujarat, Himachal Pradesh, Karnataka, Madhya Pradesh, Maharashtra and North-Eastern states) not even one-third area was irrigated.

The correlation between the adoption indices (AI1, AI2) and irrigation varied from 0.73 to 0.79, depending on the consideration of the states in the hilly region or the state of Kerala. This means that adoption of technology is primarily governed by the availability of irrigation because irrigation reduces the natural risk in the agricultural enterprise. Therefore, the expansion and improvement in irrigation infrastructure should be the central focus for raising the technology adoption level. As per the estimates of land-use statistics by the Agriculture Department, the net irrigated area in the country has increased more than 2.5-times during the past 50 years, registering an annual growth of 6.92 per cent (Throat and Sirohi, 2004). Although the country has made progress in development of its water resources, a lot remains to be achieved in terms of improving utilization operational efficiency, management of water resources and promoting a regionally equitable irrigation infrastructure.

The parameters like *organizations* (number of extension organisations per ten thousands ha of NSA), *banks* (number of banks per lakh hectares of NSA), *road* (length of roads per 100 square km of geographical area), *markets* (number per thousands hectares of NSA), and rural *literacy* (per cent) were also studied with respect to their association with the adoption of improved agricultural practices (Table 5). The parameter *organization* was observed significant at 10 per cent level when the states of HP, J&K and Kerala were excluded from the computation of correlation. It is an indication of the need for improvement in the penetration of extension services to interior of the villages. Correlation of the parameters *bank*, *markets*, *road* and *literacy* with the AI was positive (after excluding the outlier states in the correlation analysis), but not significant even up to 10 per cent level. This does not mean that these factors were not important for the adoption but they had failed to show impact because of one or more of the following reasons:

- Disparities in development and access in rural areas,
- Lack of efficiency and effectiveness,
- Lack of full-fledged as well as minimum infrastructure in the rural areas,
- Reluctance of the staff to work in less-developed villages,
- Politicization and over-bureaucratisation,
- Misuse of loans and persistent loan delinquency,

Table 5. Correlation between adoption index and individual infrastructural and developmental parameters for different sets of states

Infrastructural or developmental parameters	Major 17 states		All 17 states excluding					
			Kerala		HP, JK		HP, JK, Kerala	
	r	Sig	r	Sig	r	Sig	r	Sig
Per cent area under irrigation	0.768**	0.000	0.750**	0.001	0.750**	0.001	0.725**	0.003
Research and extension organisations per 10000 hectares of NSA	-0.265	0.303	-0.252	0.347	0.185	0.509	0.490	0.075
Road length (km) per 100 sq km of geographical area	-0.127	0.628	0.181	0.503	-0.206	0.462	0.113	0.699
Per cent villages connected by roads	0.418	0.095	.553*	0.026	0.365	0.180	0.513	0.060
Per cent villages connected by postal and telegraph (P&T) facility	0.114	0.663	0.451	0.079	0.067	0.812	0.432	0.123
Annual credit: Rs/ha of NSA	0.346	0.174	0.631**	0.009	0.347	0.206	0.668**	0.009
Per capita electricity consumed (kWh)	0.746**	0.001	0.728**	0.001	0.723**	0.002	0.696**	0.006
Electricity consumed per hectare of NSA	0.858**	0.000	0.849**	0.000	0.842**	0.000	0.828**	0.000
Number of banks per lakh hectares of NSA	-0.240	0.354	-0.293	0.270	0.118	0.675	0.059	0.840
Markets per 1000 ha of geographical area	0.012	0.965	0.144	0.595	-0.074	0.793	0.065	0.825
Per cent rural literacy	-0.125	0.634	0.074	0.786	-0.048	0.865	0.301	0.295
Agricultural wages (Rs)	0.630**	0.009	.599*	0.018	0.595*	0.025	0.542	0.056
Per cent rural population below poverty line	-.495*	0.043	-.532*	0.034	-.665**	0.007	-.719**	0.004

Notes: r is the correlation coefficient and Sig refers to level of significance
* Significant at 0.05 level (2-tailed)
** Significant at 0.01 level (2-tailed)

- Wrong identification of stakeholders, and
- Low priority to rural credit on account of poor profitability and non-viability of rural finance sector.

In fact, these factors can facilitate vertical integration between farmers, processors, input-output agencies and retailers which will further facilitate knowledge and adoption of agricultural technologies.

The parameters per cent villages connected by *road* and per cent villages connected by *Postal and Telegraphic* facilities were observed to be positively correlated (Table 5).

Although state-wise density of banks was observed as not correlated with the adoption, the agricultural credit per hectare of NSA was significantly correlated with it (Table 5). Thus, in spite of failure of banking infrastructure to have some positive impact on adoption of improved cultivation practices, the on-going technological process in agricultural development coupled with changing economic scenario demand for credit in agricultural and rural development. This calls for strengthening of the credit structure by either nursing the existing system or reinforcing with new entities such as 'Self-help Groups'. Increasing the outreach of credit and maintaining the viability standard of the institutions must be the priorities for strengthening the existing credit delivery system. Banking services should also suit the seasonality in saving of farmers, technical support and market orientation to the borrowing needs of farmers, processing, marketing and infrastructural agencies. Thus, the need of the hour is not opening of more branches but improvement in functioning of the existing ones to serve as 'development bankers'.

The parameter *Electricity* offers a great scope in the development of agriculture by energisation of pump sets which are essential to tap the groundwater potential. The electricity consumption in agriculture has increased over the years from 7.1 per cent of the total electricity consumption in 1965-66 to 29.1 per cent in 1994-95 (Throat and Sirohi, 2004). The highest per capita energy consumption in agriculture was in the state of Punjab (267 kWh), followed by Gujarat and Haryana (201 kWh). Overall consumption of electricity in the agriculture sector also had similar trends. Correlation between adoption index and electricity consumption was positive and significant at 5 per cent level (Table 5). But, out of 5.87 lakh inhabited villages (as per 1991 Census), nearly 5.08 lakh villages were electrified up to May 2001. This accounts for 86.5 per cent of average all-India level of village electrification. However, the hard fact is that 80 per cent households in rural areas are still without electricity.

The parameter, *Literacy* was not observed as significantly correlated with the adoption (Table 5). Rural literacy level was more than 60 per cent in 10 out of 17 states, yet the so-called better literate states still had low adoption. The reason could be the preference of the youth for alternative employments after getting educated. Further, the existing educational infrastructure is beset with a plethora of problems ranging from poor quality of infrastructure, high dropout rates to out-dated curriculum. Thus, in order that education could create some positive impact on adoption, there should be:

(i) Education of high quality and excellence,

(ii) Extension and improvement in teaching of science at the secondary and university stages,

(iii) Vocationalisation of secondary and higher education, and

(iv) Priority to the expansion of infrastructure to meet the demand of un-served areas.

The parameter *wages* was observed as significantly and positively correlated with the adoption index at 1 per cent level, considering the data for all the states. The correlation remained positive as well as significant even after excluding the outlier states of Kerala or HP and J&K (Table 5). The reason was higher adoption demands for skilled labour to make use of machinery, etc. who in turn demand higher wages. The parameter *BPL* (Below Poverty Line) was the indicator of the status of poverty in the state. It was observed to be significantly correlated (negatively) in all cases (Table 5). This implies that poverty is the major bottleneck for adoption of selected agricultural technologies.

To study the composite effect of infrastructural development within the state and its association with the adoption of agricultural technologies, an infrastructural index was computed following the methodology explained earlier. For the development of infrastructural index, the parameters *irrigation*, *organizations*, *credit*, *electricity* and *road*s were considered (Table 6).

The computed infrastructural index was analysed for its correlation with adoption index (Figure 1). The two indices were observed to be significantly and positively correlated (correlation > 0.9) when the outlier states were excluded from the analysis (Table 6). This clearly indicates the need for development of infrastructure for increasing the adoption of agricultural technologies.

Adoption Index and its Determinants

Correlation between the hypothetical determinant variables (x_i) representing irrigation, organisation, per cent village connected by road, per cent villages having P&T facilities, credit, electricity, wages and per cent rural population below poverty line; and the dependent variable adoption index (y) suggested a direct relation (Table 5). On the basis of strong linear correlation, y was found to be a linear function of x_i. Thus, the relationship was assumed to be as depicted in Equation (8):

$$y = a + \sum_{i=1}^{n} b_i x_i \qquad ...(8)$$

where, n was the number of variables.

In the Equation (8), a was a constant and b_i represented the elasticity, i.e. how much unit change in x_i varies the dependent variable y. While using all the infrastructural variables, the resulting coefficient

Table 6. Infrastructural parameters and their correlation with the adoption index

States	Infrastructural parameters						Infrastructural Index			
	Irrigation	Organis-ations	Roads	P&T	Credit	Electri-city	II1	II2	II*1	II*2
Andhra Pradesh	41.3	16.1	85.9	54.5	19.4	995.2	0.296	0.415	0.369	0.497
Assam	21.2	29.1	74.6	13.3	9.1	9.2	0.071	0.128	0.168	0.164
Bihar	49.6	43.2	47.8	15.6	16.8	203.4	0.153	0.185	0.294	0.263
Gujarat	31.6	20.8	94.3	55.6	15.2	1113.8	0.276	0.421	0.355	0.518
Haryana	78.4	66.0	98.8	37.9	29.4	1057.2	0.414	0.560	0.660	0.745
Himachal Pradesh	18.6	286.7	44.9	21.1	20.3	18.8	0.213	0.260	*	*
Jammu & Kashmir	42.3	108.7	65.8	34.0	12.7	603.6	0.294	0.322	*	*
Karnataka	23.8	21.8	99.6	31.6	29.6	910.3	0.240	0.389	0.365	0.441
Kerala	16.6	79.3	99.2	98.7	63.1	150.1	0.354	0.548	*	*
Madhya Pradesh	33.1	16.0	28.4	13.1	10.0	501.7	0.063	0.097	0.130	0.097
Maharashtra	16.6	25.9	70.8	28.9	13.5	880.0	0.165	0.253	0.271	0.311
Orissa	34.6	39.2	49.1	17.0	11.1	31.7	0.098	0.119	0.216	0.189
Punjab	94.5	48.3	97.3	27.5	38.8	1427.4	0.395	0.631	0.671	0.747
Rajasthan	34.2	36.3	52.0	51.1	8.6	291.7	0.186	0.213	0.283	0.342
Tamil Nadu	53.6	57.3	51.2	55.7	65.4	1304.6	0.420	0.560	0.659	0.756
Uttar Pradesh	72.2	32.0	50.4	16.0	18.6	539.9	0.204	0.278	0.343	0.327
West Bengal	35.1	32.9	48.7	18.5	14.4	271.4	0.126	0.156	0.244	0.212
Correlation of II with corresponding AI							0.736	0.730	0.910	0.926

Notes: For the development of infrastructural index, all these parameters were assumed to carry equal weights.
II1 refers to the index computation using Narain *et al.* (1991)
II2 is the index computation using the standard method
II*1 is the index computation excluding the states of HP, JK and Kerala using Narain *et al.* (1991)
II*2 is the index computation excluding the states of HP, JK and Kerala using standard method

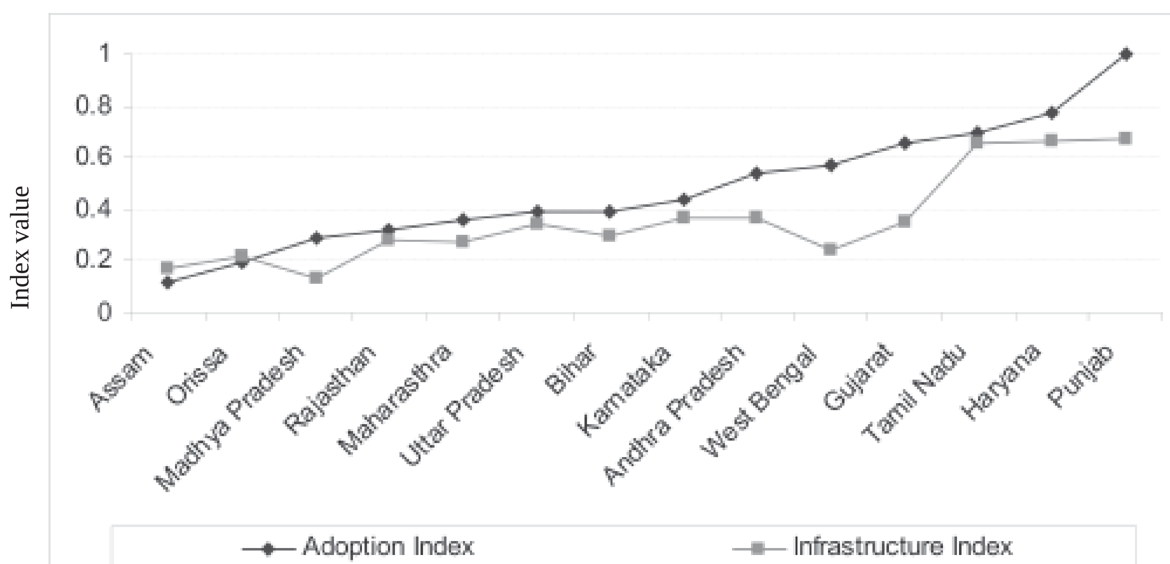

Figure 1. Adoption index vis-à-vis infrastructural index in the selected states

Table 7. Estimates of effect of different factors on adoption index

Variables	Model 1		Model 2		Model 3		Model 4	
	Coeffi-cient	Signifi-cance	Coeffi-cient	Signifi-cance	Coeffi-cient	Signifi-cance	Coeffi-cient	Signifi-cance
Constant	0.1100	0.2830	0.6640	0.0080	0.0441	0.6340	-0.126	0.2650
Irrigation	0.0050*	0.0360	0.0050*	0.0270				
Organization					0.0050*	0.0509		
Credit	0.0060	0.0770						
Electricity					0.0004**	0.0002	0.00038**	0.0001
Wages							0.007**	0.0060
BPL			-0.0100*	0.0200				
Important Statistics:								
R-squared	0.6310		0.7020		0.7800		0.8469	
Adjusted R-squared	0.5640		0.6480		0.7400		0.8191	
F	9.3980*	0.0040	12.9500	0.0010	19.9100**	0.0002	30.43**	0.00003

Notes: * Significant at 0.05 level (2-tailed)
** Significant at 0.01 level (2-tailed)

of multiple determinations (R^2), i.e. 0.895 suggested that 89 per cent of the variations in *y* were explained by the assumed independent variables.

To test whether the value of R^2 really explained the variations in *y* or might have occurred by chance, F-value was examined. The computed value of F, i.e. 5.33 meant that the regression as a whole was significant at 5 per cent level. However, all the individual coefficients were not found significant even at 10 per cent level. It was because of the problem of multi-colinearity. A test of correlation suggested that each of the selected variables was significantly correlated with one or more variables. Thus, in multiple regressions, they were collectively very significant but individually they were not significant. This meant that we could not separate out their individual contributions because they were highly correlated with each other. As a result, their coefficients in the multiple regressions had low level of significance.

To find the contribution of significant variables that could explain variations in the dependent variable, regression was carried out using the appropriate combination of variables (Table 7). Other combinations of independent variables did not result into significant coefficients. Model 1 (*irrigation, credit*) with $R^2 = 0.63$ and Model 2 (*irrigation, BPL*) with $R^2 = 0.70$, Model 3 (*organization, electricity*) with $R^2 = 0.78$ and Model 4 (*electricity, wages*) with $R^2 = 0.84$, were found to be the best models with significant coefficients at 5 per cent level of significance. Negative coefficient of the variable *BPL* (Model 2) showed that decreasing the rural population below poverty line would improve the adoption index. All other coefficients were positive, thus improving the irrigation facilities, number of extension organisations, credit, electricity and wages had the potential to improve the adoption of selected agricultural technologies.

Conclusions and Policy Implications

The study has estimated the state-wise index of adoption of selected agricultural technologies in the country based on household level information provided by NSSO data using different methods. Adoption index estimated by both the methods has been found highly correlated. Punjab, Haryana and Gujarat are the top ranking agricultural technology adopting states, while Assam has the lowest rank in this adoption. Correlation analysis between state-wise adoption index and the state-wise agricultural productivity has shown a positive and highly significant correlation. Based on this, it has been inferred that increase in the application of fertilizers, weedicides, pesticides, improved seeds and higher use of tractors would improve the productivity of agriculture. Similarly, determinants like irrigation, organizations, credit, electricity, per cent villages connected by road, per cent villages connected by postal and telegraphic facilities and wages have been observed positively correlated, while per cent rural population below poverty line has been found negatively correlated with the technology adoption index. This underscores the need for improving infrastructure to increase adoption which would in turn increase per hectare crop productivity. The functional analysis has revealed that infrastructural parameters, viz. electricity, irrigation, credit and organizations, positively influence the adoption of improved technologies. It has been concluded that policies which help in increasing the availability of electricity, irrigation and institutional credit and improve the access to the extension organizations would lead to increase in agricultural productivity.

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