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Review

Inter-state variations in technical efficiency in Indian Agriculture: A non-parametric frontier approach

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The study endeavors to evaluate the efficiency performance of Indian Agriculture over the period of 1971 to 2004 using the technique of Data Envelopment Analysis. The empirical results reveal that the agriculture sector in India is operating with technical inefficiency to the tune of 18% which is high by all standards. Further, it has been observed that the technical inefficiency is mainly caused by improper selection of production scale, thus calls for an urgent need of cooperative farming to reap the potential of economies of scale in agriculture sector. The application of panel data Tobit regression analysis aiming to examine the impact of various explanatory variables on efficiency measures reveal that mechanization of agriculture, development of irrigation and an increased supply of electricity have positive effect on all the three measure of efficiency. However, the policy of frequent increase in supply of credit to agriculture sector fails to bring any improvement in agricultural efficiency of India as the effect of this policy variable is negative on all the three measure of efficiency.

Key words: Technical efficiency, Indian Agriculture, data envelopment analysis, Tobit regression.

INTRODUCTION

The agricultural growth with optimum use of resources is prerequisite and essential to ensure the food security, earning foreign exchange and to get rid from poverty and hunger. The slow growth of agriculture with low levels of income, saving and investment in one hand and increased population along with high growth of other sectors, thereby increase in demand for wage goods, requires continuous growth of this sector with the existing constraint of resources in general and land in particular. Therefore, the growth of agriculture sector through improved management and optimum scale of production is an important and imperative issue in agricultural economics since it made distinction between top performing and poorer performing states. In a public environment, the performance measurement allows the resources to be allocated to the states which are the most productive and in a competitive environment it allows poor performers to understand the quality of their performance and to apply benchmarking techniques to guide them toward improvement. However, the agriculture sector operate in multi-input multi-output environment therefore, to understand performance in terms of efficiency, the set of relevant inputs and outputs need to be considered simultaneously.

The concept of efficiency in the literature refers to a firm's (state) ability to maximise outputs (such as farm produce in agriculture) for a given set of inputs (such as labour use, machine use and fertilizers, etc.), or to minimise the use of inputs given a set of outputs. A firm is said to be technically efficient if it cannot increase its

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outputs without some corresponding augmentation of inputs given the current state of production technology. Koopmans (1951) defines the efficiency as “A possible point in the commodity space is called efficient whenever an increase in one of its coordinates (the net output of one good) can be achieved only at the cost of a decrease in some other coordinate (the net output of another good).” The term commodity space is more commonly referred to as the production possibility set, meaning a set of all points, representing input and output pairs such that the input can be used to produce the output. Thus a technically inefficient producer could, by improving its performance, produce its output with less of at least one input, or could use its inputs to produce more of at least one output.

There are several approaches to measure the efficiency, such as Stochastic frontier analysis (SFA), thick frontier approach (TFA), Distribution Free Approach (DFA), and data envelopment analysis (DEA). Berger et al. (1993) and Berger and Humphrey (1997) provide key discussions and comparisons of these methods to measure the efficiency. However, the literature investigating efficiency in agriculture has been dominated by two methodologies: Non-parametric data envelopment analysis (DEA) (Charnes et al., 1978) and the parametric stochastic frontier analysis (SFA), based on the ideas of Aigner et al. (1977). The choice of non-parametric DEA is preferred because it requires the smallest number of observations, as parametric techniques specify a large number of parameters, making it necessary to have available a large number of observations (Maudos et al., 2002a, b). The other advantages of DEA are that it does not require any assumption to be made about the distribution of inefficiency and that it does not require a particular functional form in order to determine the most efficient decision making units (DMUs). On the other hand, the shortcomings of DEA are that, it assumes data to be free of measurement error and it is sensitive to outliers. Furthermore, due to its non-parametric nature, the DEA approach does not provide as much insight into market structure and firm behavior as the parametric SFA approach does.

Although, in the recent years there has been a stream of the research studies to appraise the efficiency of agricultural sector in India yet these studies concentrated either on the efficiency of single crop or on single state (Shanmugam, 2003; Kalirajan and Bhende, 2007; Shanmugam and Venkataramani, 2006a; Sengupta and Kundu, 2006; Goyal et al., 2006).

The present paper endeavors to measure the technical efficiency of fourteen major agricultural states by driving the composite indices of value of produce per hectare, value of labour use per hectare and machine use per hectare (Capital utilisation) of all principal crops. The study undertakes with the two specific objectives: *Firstly* to measure the technical and scale efficiency of Indian agriculture using the mathematical based liner programming technique DEA and *Secondly* to identify the factors affecting the technical efficiency of Indian agriculture by using panel data Tobit regression model.

MEASURING TECHNICAL EFFICIENCY WITH DEA: A METHODOLOGICAL FRAMEWORK

The measurement of technical efficiency is based upon deviations of observed output or input vectors from the best production or efficient production frontier. If a production units’ actual production point lies on the frontier it is perfectly efficient. If it deviates from the frontier then it is technically inefficient, with the ratio of the actual to potential production defining the level of efficiency of the individual firm. Our measure of technical efficiency provides an indication of how the use of all inputs can be minimized in the production process of a given farm, while continuing to produce the same level of output. Furthermore, the parametric and non-parametric methods are the two main approaches used to measure technical efficiency. The results from both methods are highly correlated in most cases (Wadud and White, 2000; Thiam et al., 2001), indicating that both methods are valuable and the choice can be based on a researcher’s preference.

DEA models

Farrell (1957) introduces the concept of relative efficiency, according to which, the efficiency of a decision making unit (DMU) can be evaluated by comparing it to the other DMUs in a given group. This concept was extended by Charnes et al. (1978) who developed the first DEA model, called CCR (Charnes, Cooper and Rhodes), to incorporate many inputs and outputs simultaneously. In this way, DEA provides a straightforward approach for calculating the efficiency gap between the actions of each producer and best practices, inferred from observations of the inputs used and the outputs generated by efficient firms (Wadud and White, 2000). Explicitly, DEA uses piecewise linear programming to calculate the efficient or best practice frontier of a sample of DMUs. The DMUs on this technical efficiency frontier will have an efficiency score equal to 1. Less efficient DMUs are measured in relation to the efficient ones. Moreover, different units of measurement for the various inputs and outputs can be combined within the DEA models.

The first DEA CCR model assumed constant returns to scale (CRS) which means a DMU producing an output Y, using an input X, it is feasible to produce a*Y using a*X amount of input (a is a scalar). However, in practice this may not always be observed, as increasing the input does not usually result in a proportionate increase in output. For instance, in agriculture, when the amount of irrigation water, fertiliser is increased, there is not always an equiproportional increase in crop volume. For this reason, a variable returns to scale (VRS) option might also be more considered for technical efficiency measures in the case agriculture. The first DEA model used to assess technical efficiency under the VRS assumption was developed by Banker et al. (1984) and was called the BCC (Banker, Charnes and Cooper) model.

Further, to identify whether CRS or VRS applies to production, the DEA technique has been applied to calculate and compare the efficiency values under both assumptions. The use of the VRS specification permits the calculation of technical efficiency (TE) without the scale efficiency (SE) effects (Coelli, 1996). As the scale efficiency can be obtained by the ratio TE_{CRS}/TE_{VRS} thus the values of efficiency under CRS and VRS are required to calculate the scale efficiency. Moreover the study of efficiency using DEA can be orientated toward inputs or outputs. The difference lies in whether the objective is to continue using the same amount of inputs while producing more output (output-orientated DEA), or to produce the same amount of output with fewer inputs (input-orientated DEA) In the present study the following output-oriented CCR model named after Charnes et al. (1978), has been utilised to get a scalar measure of technical efficiency

$$\left.\begin{array}{lll} & \text{Maximize } TE_{CRS}^{k} = \theta_k & \\ subject\ to: & \sum_{j=1}^{n} \lambda_j x_{ij} \leq x_{ik} & i = 1,2,...,m; \\ & \sum_{j=1}^{n} \lambda_j y_{rj} \geq \theta_k y_{rk} & r = 1,2,...,s; \\ & \lambda_j \geq 0, & j = 1,2,...,n. \end{array}\right\} \quad (1)$$

Where, θ represents the technical efficiency and hence percentage of radial increase to which output is subjected; λ_k represents the influence of k^{th} state in determining technical efficiency; $X_{i,k}$ and $Y_{i,k}$ are i^{th} and r^{th} input and output variables of the k^{th} state respectively. It is of worth mentioning here that the number of DMUs (n) should usually be considered larger than the number of inputs and outputs $(i+r)$ in order to provide a fair degree of discrimination of results.

The study is based on secondary data compiled under the scheme of Cost of Cultivation of Principal Crops in India, by Ministry of Agriculture, Government of India. The data pertaining to the period 1971 to 2004 has been taken for study purpose. However, the data relating to control variables such as irrigation development (ratio of gross irrigated area to gross cropped area), banking infrastructure (that is, credit availability/ ratio of institutional credit for agriculture to total institutional credit) and fertilizer use per hectare has been culled out from Center for Monitoring Indian Economy (CMIE) reports. The variables value of output per hectare, value of labour use per hectare, value of machine use (that is, capital use) per hectare and fertilizer use per hectare has been utilized for the study. Since the data is available in disaggregated form (crop-wise), the technique of Principal Component Analysis (PCA) has been applied to work out the composite index of all crops (Appendix Table A1 to A3). Further, to make the figures comparable over time and across states, suitable deflators have been utilized.

TECHNICAL EFFICIENCY OF INDIAN AGRICULTURE: AN EMPIRICAL ANALYSIS

Using the aforementioned data set and applying CCR model, the average efficiency level in Indian agriculture has been observed to be 0.818. The direct connotation of this result is that there exists 18.2% technical inefficiency in Indian agriculture. Thus to provide the same bundle of input, 18.2% of input could have been reduced, or utilized to produce more of agricultural output. It has been also observed that in pre-reforms period nearly 20% inefficiency was present in Indian agriculture. The wastage or resources to the tune of 20% in pre-reforms generally and maturing phase of green revolution particularly may be justified on the ground of lack of adoption of new technology due to bottlenecks of physical and financial infrastructure, hardly provide any incentive to the farmers and ultimately discouraged the efficient managerial supervision. The small size of farm which devoid the farmers to reap the economies of scale, is another important reason in this connection. The visualization of Table 1 also reveals that the impact of economic reforms is optimistic and positive on the technical efficiency of Indian agricultural. The devaluation of Rupee in 1990 and gradual opening of world markets for Indian agricultural commodities during 1991 along with the upliftment of exports ban have upbeat effect on agricultural efficiency in India. It has been observed that during the post reforms period the technical efficiency in Indian agriculture has increased by about 6% ((0.847-0.802/0.802)×100). Thus the reforms process has been observed augmenting the performance of Indian agriculture.

The inter-state analysis of OTE depicts that the state of Tamil Naidu has been observed to be the best practice state with an average OTE score 0.966. Except 12 years, out of 39, the State of Tamil Naidu has obtained an OTE score equal to unity, thus identified as best practice state in 22 years. The high efficiency score of Tamil Naidu was mainly due to development of quality irrigation infrastructure in the state and also substantiates the earlier findings of Kalirajan (2006) and Shanmugam and Venkataramani (2006b). In comparison of Tamil Naidu, the state of Gujarat is worst performer state of the sample. The worse performance of industrially advance state may justified on the ground that state is drought-prone as only 24% of its cropped area has assured

Table 1. Interstate variations in overall technical efficiency in Indian Agriculture.

Years	States														
	A.P.	Assam	Bihar	Gujarat	Haryana	Karnataka	M. P.	M'ra	Orissa	Punjab	Rajasthan	T. N.	U.P.	W.B.	All-India
1971/72	0.725	0.846	0.933	0.852	0.909	0.877	0.858	0.798	0.782	1.000	0.842	1.000	1.000	0.878	0.878
1972/73	0.755	0.859	0.745	0.676	0.795	0.665	0.714	0.791	0.879	1.000	0.986	1.000	1.000	0.874	0.838
1973/74	0.641	0.734	0.698	0.783	0.554	0.736	0.843	0.798	0.678	0.924	0.716	0.957	0.627	0.613	0.735
1974/75	0.615	0.768	0.846	0.504	0.732	0.562	0.672	0.855	0.784	1.000	0.792	1.000	0.857	0.709	0.764
1975/76	0.644	0.845	0.808	0.688	0.571	0.732	0.775	0.841	0.674	1.000	0.718	0.847	0.619	0.604	0.740
1976/77	0.635	0.782	0.764	0.572	0.768	0.646	0.752	0.649	0.767	1.000	0.694	1.000	0.663	0.593	0.734
1977/78	0.637	0.689	0.774	0.652	0.765	0.675	0.739	0.624	0.769	1.000	0.763	1.000	0.67	0.683	0.745
1978/79	0.642	0.829	0.642	0.568	0.611	0.703	0.739	0.837	0.687	0.896	0.793	1.000	0.759	0.683	0.742
1979/80	0.642	0.795	0.729	0.606	0.743	0.656	0.697	0.832	0.704	1.000	0.831	1.000	0.661	0.671	0.754
1980/81	0.652	0.914	0.739	0.655	0.746	0.833	0.834	0.841	0.892	0.996	0.779	1.000	0.758	0.676	0.808
1981/82	0.664	0.796	0.757	0.653	0.743	0.824	0.823	0.876	0.916	1.000	0.866	0.984	0.903	0.688	0.821
1982/83	0.725	1.000	0.987	0.646	0.745	0.834	0.859	0.632	0.874	1.000	0.841	0.847	0.759	0.816	0.826
1983/84	0.721	1.000	1.000	0.665	0.821	0.713	0.794	0.799	0.976	0.957	0.884	0.824	0.758	0.746	0.832
1984/85	0.691	0.954	0.78	0.655	0.827	0.731	0.893	0.893	0.931	0.847	0.883	0.954	0.776	0.766	0.827
1985/86	0.682	0.847	0.973	0.624	0.750	0.712	0.785	0.834	0.893	0.958	0.725	1.000	0.727	0.811	0.809
1986/87	0.67	0.834	0.885	0.642	0.816	0.715	0.848	0.812	0.934	1.000	0.764	1.000	0.878	0.821	0.830
1987/88	0.689	0.915	0.932	0.618	0.876	0.701	0.784	0.798	0.957	1.000	0.758	0.835	0.715	0.851	0.816
1988/89	0.697	0.872	0.904	0.768	0.877	0.818	0.844	0.884	0.962	0.984	0.722	1.000	0.753	0.730	0.844
1989/90	0.781	0.809	0.883	0.895	0.952	0.717	0.777	0.775	0.839	0.916	0.816	1.000	0.789	0.749	0.835
1990/91	0.710	0.901	0.854	0.644	0.845	0.715	0.747	0.755	0.992	0.889	0.763	1.000	0.799	0.837	0.818
1991/92	0.788	0.755	0.865	0.653	0.795	0.723	0.709	0.729	0.929	0.845	0.764	0.958	0.764	0.862	0.796
1992/93	0.801	0.820	0.886	0.664	0.838	0.836	0.831	0.837	0.983	0.847	0.815	1.000	0.876	0.833	0.848
1993/94	0.783	0.905	0.963	0.763	0.903	0.830	0.822	0.844	1.000	1.000	0.808	0.984	0.964	0.893	0.891
1994/95	0.691	0.857	0.702	0.664	0.821	0.729	0.711	0.741	0.758	1.000	0.836	1.000	0.785	0.866	0.797
1995/96	0.804	0.862	0.936	0.645	0.905	0.739	0.723	0.746	0.886	1.000	0.736	1.000	0.831	0.776	0.828
1996/97	0.712	0.807	0.79	0.724	0.916	0.836	0.823	0.847	0.855	1.000	0.796	1.000	0.857	0.876	0.845
1997/98	0.785	0.866	0.753	0.768	0.908	0.826	0.808	0.837	0.946	0.847	0.848	1.000	0.884	0.863	0.853
1998/99	0.793	0.909	0.867	0.863	0.753	0.828	0.813	0.842	0.928	1.000	0.843	0.835	0.938	0.835	0.860
1999/00	0.781	0.858	0.760	0.735	0.824	0.736	0.758	0.795	0.852	1.000	0.713	0.896	0.877	0.821	0.815
2000/01	0.793	0.848	0.921	0.737	0.745	0.845	0.711	0.785	0.794	1.000	0.838	1.000	0.942	0.809	0.840
2001/02	0.781	0.827	0.934	0.761	0.895	0.764	0.724	0.731	0.774	1.000	0.786	1.000	0.927	0.875	0.841
2002/03	0.818	0.845	0.898	0.741	0.917	0.826	0.816	0.853	0.866	0.978	0.819	1.000	0.985	0.892	0.875
2003/04	0.754	0.822	0.894	0.796	0.912	0.815	0.843	0.813	0.825	0.947	0.809	0.927	0.984	0.832	0.855
2004/05	0.833	1.000	0.873	0.786	0.854	0.809	0.792	0.853	0.866	1.000	0.895	1.000	0.897	0.783	0.874
Entire period[#]	0.721	0.852	0.843	0.696	0.806	0.756	0.784	0.799	0.857	0.965	0.801	0.966	0.823	0.782	0.818

Table 1. Contd.

Pre-reforms	0.691	0.843	0.836	0.667	0.776	0.732	0.787	0.795	0.854	0.957	0.796	0.967	0.777	0.749	0.802
Post-reforms	0.777	0.867	0.857	0.748	0.862	0.798	0.779	0.807	0.862	0.981	0.810	0.970	0.905	0.843	0.847

Source: Author's calculations.

water supply including rainfall in 1980s (CMIE, 1988). However, low crop intensity and low sown area under HYV seeds, are the other important reasons for worse performance of the state during the study period. Thus there exists a huge variation in the technical efficiency scores between 14 major states of agriculture. It is worth mentioning here that, there exists a diminutive difference between OTE scores of the state of Punjab (0.965) and Tamil Naidu (0.966) and the same trend has been observed in the efficiency figures during the study period. Moreover, it also confirms the earlier findings of Shanmugam and Venkataramani (2006b). Furthermore, six states mainly, Assam, Bihar, Orissa, Punjab, Tamil Naidu and U.P. have been observed to be operating with above all India overall Technical efficiency score and the remaining eight states are operating below all India average. The positive impact of economic reforms in Indian agriculture supported by the inference that all the 14 states have experienced an increase in efficiency score during the post reforms period

Further, it has been theoretically observed that the OTE can further be decomposed into pure technical efficiency and scale efficiency. The PTE is, a measure of managerial performance at farm level where as the SE reflects the choice of optimum scale of production. Therefore, PTE is devoid of scale effect and can be measured subject to the assumption of the variable returns to scale. The economist view is that these two measures are the sources of overall technical efficiency. These sources have been discussed as follows.

Source of technical efficiency in Indian Agriculture

The visualization Table 2 reveals that 15.5% points of 18.2% of overall technical inefficiency (OTIE) has been contributed by scale factor. Thus, the remaining inefficiency is caused by the managerial sub performance. Hence, it is evident from these facts that the scale inefficiency is major source of OTIE in Indian agriculture. However, the management at farm level is not serious matter of concern. The major policy implication emerging from this result is that to obtain reap the economies of scale and operate on efficiency frontier, the Indian farmers need to increase the size of their holdings. However, in order to increase the production scale, two possible moves are available to Indian farmers (i) intensive agriculture (ii) extensive agriculture. The scope of latter method is relatively less effective because of inelastic supply of land and increasing pressure of population in India. However, the earlier technique which is although area neutral but resource non-neutral thus, the panacea for these two problems is to encourage co-operative farming in Indian agriculture. When farmers will pool their resources including land, then size of land will also increase along with the benefit of increasing the potential to apply modern technology on given piece of land. Therefore, both objectives, that is, extensive agriculture with intensive farming can be realized with the help of cooperative farming.

The analysis of two sub periods is in the same lines as observed for OTE. Both PTE and SE have been increased during the second sub-period at both All-India and at State level. Four states namely Assam, Madhya Pradesh, Punjab and Tamil Naidu have been observed benchmark states in terms of managerial practice as the PTE of these states amounts to unity. The state of Uttar Pradesh has also been observed benchmark in almost all the years except 1975-1976 (Table 3). Moreover, the state of Karnataka has also been managerially efficient in almost all the years baring 1981-82, 1982-83 and 1988-89. The high managerial efficiency was mainly because of small size of farm thus it is easy for the farmer to supervise the small farm efficiently. However, the minimum managerial efficiency has been observed for state of Gujarat. The observed managerial efficiency in agriculture of Gujarat is not more than 10%. The managerial inefficiency exists because of small size of farm along with the lack of irrigation facilities and production of low value crops, yields a lesser amount of incentive and ultimately discourages the inducement of supervision of the farm.

The analysis of scale efficiency reflects that, scale inefficiency varies from the minimum of 3.4% for state of Tamil Naidu to maximum of 24.3% for the state of Karnataka. Thus there exists a huge variation in scale efficiency among 14 major agriculture states of India. However, 8 states namely Assam, Bihar, Haryana, Maharashtra, Orissa, Punjab, Tamil Naidu and West Bengal have been observed operating above all India average efficiency of 0.845. Moreover an improvement in SE in all the states has also been observed during Post reform

Table 2. Interstate variations in scale efficiency in Indian Agriculture.

Years	States														
	A.P.	Assam	Bihar	Gujarat	Haryana	Karnataka	M. P.	Maharashtra	Orissa	Punjab	Rajasthan	T. N.	U.P.	W. B.	All-India
1971/72	0.733	0.846	0.933	0.903	0.909	0.877	0.858	0.833	0.878	1.000	0.842	1.000	1.000	0.935	0.896
1972/73	0.95	0.859	0.745	0.676	0.956	0.665	0.714	0.875	0.879	1.000	0.986	1.000	1.000	0.908	0.872
1973/74	0.808	0.734	0.714	0.797	0.682	0.736	0.843	0.895	0.700	0.924	0.716	0.957	0.627	0.663	0.771
1974/75	0.711	0.768	0.846	0.517	0.976	0.562	0.672	0.951	0.784	1.000	0.792	1.000	0.857	0.740	0.806
1975/76	0.687	0.845	0.808	0.783	0.724	0.732	0.775	0.922	0.737	1.000	0.718	0.847	0.633	0.741	0.782
1976/77	0.659	0.782	0.765	0.686	0.877	0.646	0.752	0.876	0.917	1.000	0.694	1.000	0.663	0.662	0.784
1977/78	0.76	0.689	0.774	0.859	0.996	0.675	0.739	0.737	0.911	1.000	0.763	1.000	0.670	0.803	0.813
1978/79	0.765	0.829	0.687	0.863	0.835	0.703	0.739	0.896	0.687	0.896	0.793	1.000	0.759	0.816	0.805
1979/80	0.687	0.795	0.729	0.750	0.827	0.656	0.697	0.889	0.704	1.000	0.831	1.000	0.661	0.800	0.788
1980/81	0.669	0.914	0.739	0.766	0.851	0.833	0.834	0.851	0.892	0.996	0.779	1.000	0.758	0.718	0.829
1981/82	0.724	0.796	0.757	0.776	0.773	0.846	0.823	0.915	0.916	1.000	0.866	0.984	0.903	0.770	0.846
1982/83	0.775	1.000	0.987	0.721	0.860	0.841	0.859	0.728	0.874	1.000	0.841	0.847	0.759	0.834	0.852
1983/84	0.815	1.000	1.000	0.681	0.879	0.713	0.794	0.808	0.976	0.957	0.884	0.824	0.758	0.861	0.854
1984/85	0.699	0.954	0.814	0.725	0.864	0.731	0.893	0.893	0.931	0.847	0.883	0.954	0.776	0.915	0.849
1985/86	0.765	0.847	0.973	0.697	0.837	0.712	0.785	0.867	0.893	0.958	0.725	1.000	0.727	0.957	0.839
1986/87	0.798	0.834	0.943	0.751	0.851	0.715	0.848	0.824	0.934	1.000	0.764	1.000	0.878	0.875	0.858
1987/88	0.775	0.915	0.932	0.738	0.896	0.701	0.784	0.824	0.957	1.000	0.758	0.835	0.715	0.910	0.839
1988/89	0.736	0.872	0.928	0.821	0.892	0.818	0.844	0.928	0.962	0.984	0.722	1.000	0.753	0.809	0.862
1989/90	0.829	0.809	0.883	0.949	0.952	0.717	0.777	0.890	0.839	0.916	0.816	1.000	0.789	0.871	0.860
1990/91	0.748	0.901	0.854	0.754	0.966	0.715	0.747	0.886	0.992	0.889	0.763	1.000	0.799	0.908	0.852
1991/92	0.830	0.755	0.865	0.782	0.868	0.723	0.709	0.813	0.929	0.845	0.764	0.958	0.764	0.946	0.825
1992/93	0.908	0.82	0.886	0.818	0.908	0.836	0.831	0.880	0.983	0.847	0.815	1.000	0.876	0.862	0.876
1993/94	0.788	0.905	0.979	0.769	0.903	0.830	0.822	0.844	1.000	1.000	0.808	0.984	0.964	0.925	0.894
1994/95	0.723	0.857	0.702	0.687	0.844	0.729	0.711	0.753	0.907	1.000	0.836	1.000	0.785	0.897	0.817
1995/96	0.835	0.862	0.936	0.647	0.905	0.739	0.723	0.822	0.886	1.000	0.736	1.000	0.831	0.791	0.837
1996/97	0.742	0.807	0.790	0.730	0.978	0.836	0.823	0.900	0.855	1.000	0.796	1.000	0.857	0.920	0.860
1997/98	0.873	0.866	0.753	0.899	0.945	0.826	0.808	0.837	0.946	0.847	0.861	1.000	0.884	0.863	0.872
1998/99	0.822	0.909	0.867	0.905	0.753	0.840	0.813	0.856	0.928	1.000	0.843	0.835	0.938	0.849	0.868
1999/00	0.800	0.858	0.849	0.767	0.920	0.736	0.758	0.889	0.852	1.000	0.713	0.896	0.877	0.918	0.845
2000/01	0.829	0.848	0.921	0.782	0.844	0.845	0.711	0.834	0.794	1.000	0.838	1.000	0.942	0.887	0.863
2001/02	0.794	0.827	0.951	0.832	0.954	0.764	0.724	0.773	0.774	1.000	0.786	1.000	0.927	0.882	0.856
2002/03	0.871	0.845	0.898	0.771	0.992	0.826	0.816	0.894	0.866	0.978	0.846	1.000	0.985	0.922	0.894
2003/04	0.782	0.822	0.92	0.823	0.912	0.815	0.843	0.813	0.825	0.947	0.809	0.927	0.984	0.847	0.862
2004/05	0.865	1.000	0.924	0.913	0.854	0.809	0.792	0.923	0.866	1.000	0.895	1.000	0.897	0.847	0.899
Entire period#	0.781	0.852	0.854	0.775	0.882	0.757	0.784	0.86	0.876	0.965	0.802	0.966	0.823	0.849	0.845

Table 2. Contd.

Pre-reforms	0.758	0.844	0.842	0.762	0.870	0.729	0.785	0.867	0.871	0.962	0.795	0.962	0.774	0.831	0.832
Post-reforms	0.818	0.863	0.875	0.796	0.901	0.802	0.783	0.848	0.883	0.970	0.814	0.972	0.904	0.878	0.865

Source: Author's calculations.

Table 3. Interstate variations in pure technical efficiency in Indian Agriculture.

Years	States														
	A.P.	Assam	Bihar	Gujarat	Haryana	Karnataka	M. P.	Maharashtra	Orissa	Punjab	Rajasthan	T. N.	U.P.	W. B.	All –India
1971/72	0.988	1.000	1.000	0.944	1.000	1.000	1.000	0.958	0.891	1.000	1.000	1.000	1.000	0.939	0.980
1972/73	0.795	1.000	1.000	1.000	0.832	1.000	1.000	0.904	1.000	1.000	1.000	1.000	1.000	0.963	0.963
1973/74	0.793	1.000	0.977	0.983	0.812	1.000	1.000	0.892	0.969	1.000	1.000	1.000	1.000	0.924	0.953
1974/75	0.865	1.000	1.000	0.974	0.750	1.000	1.000	0.809	1.000	1.000	1.000	1.000	1.000	0.958	0.954
1975/76	0.937	1.000	1.000	0.879	0.789	1.000	1.000	0.912	0.915	1.000	1.000	1.000	0.978	0.815	0.944
1976/77	0.964	1.000	0.999	0.834	0.876	1.000	1.000	0.741	0.836	1.000	1.000	1.000	1.000	0.896	0.939
1977/78	0.838	1.000	1.000	0.759	0.768	1.000	1.000	0.847	0.844	1.000	1.000	1.000	1.000	0.851	0.921
1978/79	0.839	1.000	0.934	0.658	0.732	1.000	1.000	0.934	1.000	1.000	1.000	1.000	1.000	0.837	0.923
1979/80	0.935	1.000	1.000	0.808	0.898	1.000	1.000	0.936	1.000	1.000	1.000	1.000	1.000	0.839	0.958
1980/81	0.974	1.000	1.000	0.855	0.877	1.000	1.000	0.988	1.000	1.000	1.000	1.000	1.000	0.942	0.974
1981/82	0.917	1.000	1.000	0.842	0.961	0.974	1.000	0.957	1.000	1.000	1.000	1.000	1.000	0.893	0.967
1982/83	0.936	1.000	1.000	0.896	0.866	0.992	1.000	0.868	1.000	1.000	1.000	1.000	1.000	0.978	0.966
1983/84	0.885	1.000	1.000	0.976	0.934	1.000	1.000	0.989	1.000	1.000	1.000	1.000	1.000	0.866	0.975
1984/85	0.988	1.000	0.958	0.903	0.957	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.837	0.974
1985/86	0.891	1.000	1.000	0.895	0.896	1.000	1.000	0.962	1.000	1.000	1.000	1.000	1.000	0.847	0.963
1986/87	0.840	1.000	0.938	0.855	0.959	1.000	1.000	0.986	1.000	1.000	1.000	1.000	1.000	0.938	0.965
1987/88	0.889	1.000	1.000	0.837	0.978	1.000	1.000	0.968	1.000	1.000	1.000	1.000	1.000	0.935	0.971
1988/89	0.947	1.000	0.974	0.936	0.983	1.000	1.000	0.953	1.000	1.000	1.000	1.000	1.000	0.902	0.978
1989/90	0.942	1.000	1.000	0.943	1.000	1.000	1.000	0.871	1.000	1.000	1.000	1.000	1.000	0.860	0.972
1990/91	0.949	1.000	1.000	0.854	0.875	1.000	1.000	0.852	1.000	1.000	1.000	1.000	1.000	0.922	0.960
1991/92	0.949	1.000	1.000	0.835	0.916	1.000	1.000	0.897	1.000	1.000	1.000	1.000	1.000	0.911	0.964
1992/93	0.882	1.000	1.000	0.812	0.923	1.000	1.000	0.951	1.000	1.000	1.000	1.000	1.000	0.966	0.966
1993/94	0.994	1.000	0.984	0.992	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.965	0.995
1994/95	0.956	1.000	1.000	0.966	0.973	1.000	1.000	0.984	0.836	1.000	1.000	1.000	1.000	0.965	0.977
1995/96	0.963	1.000	1.000	0.997	1.000	1.000	1.000	0.908	1.000	1.000	1.000	1.000	1.000	0.981	0.989
1996/97	0.959	1.000	1.000	0.992	0.937	1.000	1.000	0.941	1.000	1.000	1.000	1.000	1.000	0.952	0.984
1997/98	0.899	1.000	1.000	0.854	0.961	1.000	1.000	1.000	1.000	1.000	0.984	1.000	1.000	1.000	0.978
1998/99	0.965	1.000	1.000	0.954	1.000	0.986	1.000	0.984	1.000	1.000	1.000	1.000	1.000	0.984	0.990

Table 3. Contd.

1999/00	0.976	1.000	0.895	0.958	0.896	1.000	1.000	0.894	1.000	1.000	1.000	1.000	1.000	0.894	0.965
2000/01	0.957	1.000	1.000	0.942	0.883	1.000	1.000	0.941	1.000	1.000	1.000	1.000	1.000	0.912	0.973
2001/02	0.984	1.000	0.982	0.915	0.938	1.000	1.000	0.946	1.000	1.000	1.000	1.000	1.000	0.992	0.982
2002/03	0.939	1.000	1.000	0.961	0.924	1.000	1.000	0.954	1.000	1.000	0.968	1.000	1.000	0.967	0.979
2003/04	0.964	1.000	0.972	0.967	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.982	0.991
2004/05	0.963	1.000	0.945	0.861	1.000	1.000	1.000	0.924	1.000	1.000	1.000	1.000	1.000	0.924	0.972
Entire period#	0.925	1.000	0.987	0.901	0.914	0.998	1.000	0.930	0.979	1.000	0.998	1.000	0.999	0.921	0.968
Pre-reforms	0.907	1.000	0.984	0.879	0.888	0.998	1.000	0.915	0.974	1.000	1.000	1.000	0.998	0.897	0.960
Post-reforms	0.953	1.000	0.982	0.936	0.956	0.998	1.000	0.955	0.987	1.000	0.996	1.000	1.000	0.960	0.980

Source: Author's Calculations.

period in comparison of Pre reform period (Table 2).

Factors causing technical efficiency

The differences in technical efficiency across Indian states may exists because of a variety of factors such as access to technology, structural rigidities, development of financial and irrigation infrastructure, etc. In order to examine the influence of environment factors on technical efficiency the technique of regression analysis has been utilised. As the measures of technical efficiency are also censored by the range (0,1], the simple OLS regression model is inappropriate in the present context. Thus, the technique of panel data Tobit regression model has been utilised to ascertain the impact of environmental variables on the three measures of efficiency (Kumar and Arora, 2010). In present study, the explanatory variables capital intensity (K/L), ratio of gross cropped area to gross irrigated area (GCA/GIA), that is, the proxy for irrigation infrastructure, ratio of institutional agriculture credit to total credit (Credit Availability), that is, the proxy for financial infrastructure and electricity use (Electricity) have been used to explain efficiency measures. The variable capital intensity (K/L) is defined as composite index of machine use per unit of labour cost, used as a measure of relative degree of mechanization of agriculture sector. High capital intensity signifies a greater degree of mechanization and expected to facilitate larger efficiency. However, in some cases, an increase in machine use per unit of labour cost can also affect the efficiency adversely. Therefore, the variable (K/L) can influence the technical efficiency measures in both ways, that is, positively or negatively. The variable (GCA/GIA) is defined as the ratio of gross cropped area to gross irrigated area and used as a proxy for irrigation infrastructure. It is hypothesized that the development of irrigation facilities has a positive relationship with the technical efficiency. The variable Credit Availability represents the availability of institutional credit for the development of agriculture and highlights the impact of financial assistance on overall and managerial performance, that is, higher credit availability lead to higher efficiency, and vice-versa. This variable has also been hypothesized to affect technical efficiency positively. The variable Electricity represents the use of electric energy by the agriculture sector. Since the energy use has positive impact on the development it has been hypothesized that the variable has positive relationship with efficiency. The following models (2) and (3) have been estimated with x_{it} consisting of three variable viz., (K/L), GCA/GIA, Credit Availability and Electricity Use and y_{it} consisting of one of the measures of technical efficiency (that is, OTE, PTE and SE). The one way fixed effect panel data *Tobit* model for observation (state) *i* at time *t* can be defined as follows:

$$\left.\begin{array}{l} y_{it}^{*} = \sum_{j=1}^{N} \alpha_j z_{ij} + \sum_{j=1}^{k} \beta_j x_{it}^{j} + \varepsilon_{it} \\ y_{it} = y_{it}^{*}, \text{ if } y_{it}^{*} < 1, \quad \text{and} \\ y_{it} = 1, \quad \text{otherwise} \end{array}\right\} \tag{2}$$

where, z_{ij}=1 if *i=j* and 0 elsewhere and $\varepsilon_{it} \sim IIN(0, \sigma_{\varepsilon}^2)$. However, x_{it}^{j} represents the j^{th} explanatory variable and β_j are corresponding parameters. The y_{it}^{*} is a latent variable and y_{it} is

Table 4. Factors causing overall, pure technical and scale efficiency: An application of fixed and random Tobit regression.

Panel A: Fixed effect results			
Independent variable	***Measure of technical efficiency***		
	OTE	***PTE***	***SE***
Constant (β_0)	0.7482 (0.000)	0.998 (0.000)	0.784 (0.000)
Credit availability (β_1)	(-) 0.01934 (0.009)	(-) 0.0150 (0.0041)	(-) 0.0034 (0.000)
Electricity consumption (β_2)	2.83 E-06 (0.006)	3.03 E-06 (0.000)	1.25 E-06 (0.007)
Irrigation development (β_3)	0.3101 (0.000)	0.1902 (0.007)	0.2421 (0.000)
Machine use per labour unit (β_4)	0.1164(0.008)	0.0089 (0.000)	0.0012 (0.008)
ANOVA F-test $\left(Null \sum_{j=1}^{N} \alpha_j = 0 \right)$	26.13 (0.000)	19.69 (0.000)	15.02 (0.000)
Panel B: Random effect results			
Independent *variable*	***Measure of technical efficiency***		
	OTE	***PTE***	***SE***
Constant (β_0)	0.7141 (0.000)	1.0381 (0.000)	0.7643 (0.000)
Credit availability (β_1)	(-) 0.0133 (0.004)	(-) 0.2221 (0.002)	(-) 0.0090 (0.005)
Electricity consumption (β_2)	3.10 E-06 (0.004)	3.98 E-06 (0.001)	1.10 E-06 (0.004)
Irrigation development (β_3)	0.2534 (0.000)	0.1632 (0.001)	0.1995 (0.000)
Machine use per labour unit (β_4)	0.0605 (0.009)	0.0041 (0.007)	0.0049 (0.002)
Wald (χ^2)	53.82 (0.000)	32.31 (0.000)	27.72 (0.000)
LM-test (Null σ_u=0)	0.7191 (0.000)	0.4344 (0.000)	0.570 (0.000)
LR-test (Null σ_u=0)	0.8065 (0.000)	0.6717 (0.000)	0.7945(0.000)

Figures in parenthesis are p-values; ** and * signify that coefficient is significant at 5 and 10% level of significance. Source: Author's calculations.

the dependent variable. Further, the random effects panel data Tobit model can be written as:

$$\left.\begin{array}{l} y_{it}^{*} = \sum_{j=1}^{k} \beta_j x_{it}^{j} + \mu_i + v_{it} \\ y_{it} = y_{it}^{*}, \text{ if } y_{it}^{*} < 1, \ and \\ y_{it} = 1, \quad otherwise \end{array}\right\} \quad (3)$$

The estimated results of aforementioned *Tobit* regression models are presented in the Table 4. The inference of the significance of individual state effect has been tested through executing *ANOVA F-Statistics* for fixed effect model and Lambda-Max (LM) and likelihood-ratio (LR) tests for random effect model. All these statistics have been found to be significant at 5% level of significance, and therefore, advocate the use of panel data models (that is, fixed/random effect models).

Table 4 provides the results for both fixed and random effect models which have been estimated and it has been observed that all the four variables are significantly affecting, three measures of efficiency. The impact of three variables electricity use, capital intensity and irrigation infrastructure is positive whereas the variable credit negatively causing efficiency performance in Indian agriculture. Thus the impact of former three variables on efficiency is in accordance of our *a-priori* expectations. However, the positive impact of (K/L) capital intensity can be justified on the grounds of that relative mechanization of agriculture increase the productivity of labour and thereby improve the efficiency in Indian agriculture. Further, the negative impact of credit availability can be advocated on the grounds that the credit which is available for farming purpose is not utilized at farm level. Hence, the increasing availability of credit to agriculture is unable to improve the efficiency in Indian agriculture.

CONCLUSION

The average efficiency level in Indian agriculture to the tune of 0.818 indicates that nearly 18% wastage of inputs could be utilized to produce more of agricultural output. It has been observed that the dominant source of OTIE is scale inefficiency whereas managerial inefficiency is relatively meager source of inefficiency. Moreover, the notable variation exists in the OTE ranging from 96.6% in case of Tamil Naidu to 69.6% for the state of Gujarat. It is worth mentioning here that the dominance of scale inefficiency (that is, SIE) as a source of OTIE is pervasive phenomenon and not limited to a particular state. In sum, in each state, the improper scale of production due to small size of holdings is the main cause of overall technical inefficiency.

From the comparative analysis of efficiency measures between pre- and post-reforms period, it has been observed that the economic reforms process exerted positive impact on the efficiency of Indian agriculture at both national and state levels. This is evident from the fact that almost all the fourteen major agricultural states have experienced an improvement in average efficiency score during the post-reforms period relative to pre-reforms period.

The panel data Tobit regression analysis aiming to examine the impact of various explanatory variables on efficiency measures reveals that relative increase in mechanization of agriculture and development of irrigation along with the increased supply of electricity have positive effect on all the measure of efficiency. However, the policy of frequent increase in supply of credit to agriculture sector will fails to bring any improvement in agricultural efficiency of India as the relationship is negative with all the three measure of efficiency. Therefore, the analysis advocates the impositions of some checks on credit delivery mechanism.

On the whole, our empirical analysis presents high levels of scale inefficiency in Indian agriculture due to the small farm holdings can only corrected by increasing the scale of production. Thus two possible moves are available to Indian farmers (i) intensive agriculture (ii) extensive agriculture. The scope of latter method is relatively less effective because of inelastic supply of land and increasing pressure of population in India. However, the earlier technique which is although area neutral but resource non-neutral thus the panacea for these two problems is to encourage co-operative farming in Indian agriculture. When farmers will pool their resources, then size of land will also increase along with the benefit of increasing the potential to apply modern technology on given piece of land. Therefore, both objectives, that is, extensive agriculture with intensive farming can be realized with the help of cooperative farming.

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APPENDIX

Table A1. Weights of value of output per hectare used to drive composite index of output.

	A.P.	Assam	Bihar	Gujarat	Haryana	Karnataka	M. P.	Maharashtra	Orissa	Punjab	Rajasthan	T. N.	U.P.	W. B.
Paddy	0.212123	0.50	0.220386	N.A.	0.139085	0.285808	0.075684	N.A.	0.004115	0.340518	N.A.	0.341075	0.150889	0.50
Wheat	N.A.	N.A.	0.226781	N.A.	0.217589	N.A.	0.172399	N.A.	N.A.	0.306783	0.18873	N.A.	0.145718	N.A.
Jowar	0.155321	N.A.	N.A.	N.A.	N.A.	0.06532	0.129732	0.290078	N.A.	N.A.	0.125896	N.A.	N.A.	N.A.
Bajara	N.A.	N.A.	N.A.	0.358594	0.166412	N.A.	N.A.	N.A.	N.A.	N.A.	0.239781	N.A.	0.1433	N.A.
Maize	0.174335	N.A.	0.24164	N.A.	N.A.	N.A.	0.14124	N.A.	N.A.	N.A.	0.217822	N.A.	0.125503	N.A.
Moong	0.166205	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	0.496835	N.A.	N.A.	N.A.	N.A.	N.A.
Urad	0.166205	N.A.	N.A.	N.A.	N.A.	N.A.	0.08547	N.A.	N.A.	N.A.	N.A.	N.A.	0.086581	N.A.
Ground Nut	0.001508	N.A.	N.A.	0.354155	N.A.	0.102323	N.A.	0.311557	0.495674	N.A.	N.A.	0.192204	N.A.	N.A.
Cotton	0.122737	N.A.	N.A.	0.287251	0.049106	0.254369	0.15785	0.294546	N.A.	0.077772	N.A.	0.161852	N.A.	N.A.
Sugarcane	0.001469	N.A.	0.182746	N.A.	0.115133	N.A.	N.A.	0.022373	N.A.	0.274927	N.A.	0.30487	0.139732	N.A.
Jute	N.A.	0.50	0.128446	N.A.	N.A.	N.A.	N.A.	N.A.	0.003376	N.A.	N.A.	N.A.	N.A.	0.50
Gram	N.A.	N.A.	N.A.	N.A.	0.1041	N.A.	0.162373	N.A.	N.A.	N.A.	0.00885	N.A.	0.087694	N.A.
Mustard	N.A.	N.A.	N.A.	N.A.	0.208576	N.A.	N.A.	N.A.	N.A.	N.A.	0.218922	N.A.	0.120584	N.A.
Ragi	N.A.	N.A.	N.A.	N.A.	N.A.	0.241904	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
Sunflower	N.A.	N.A.	N.A.	N.A.	N.A.	0.050277	N.A.	0.081446	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
Arhar	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	0.075253	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.

The values of weights are square of loadings of first principal component. Source: Author's calculations.

Table A2. Weights of value of labour use per hectare used to drive composite index of labour.

	A.P.	Assam	Bihar	Gujarat	Haryana	Karnataka	M. P.	Maharashtra	Orissa	Punjab	Rajasthan	T. N.	U.P.	W. B.
Paddy	0.078689	0.50	0.032591	N.A	0.163308	0.11258	0.032371	N.A	0.42919	0.398415	N.A.	0.24807	0.02413	0.50
Wheat	N.A	N.A	0.339933	N.A	0.0889	N.A	0.252657	0.025278	N.A	0.410669	0.214954	N.A	0.16797	N.A
Jowar	0.112853	N.A	N.A	N.A	N.A	0.07430	0.08944	N.A	N.A	N.A	0.21062	N.A	N.A	N.A
Maize	0.007989	N.A	0.220508	N.A	N.A	N.A	0.089921	N.A	N.A	N.A	0.047658	N.A	0.08925	N.A
Bajra	N.A.	N.A	N.A	0.394669	N.A	N.A	N.A	N.A	N.A	N.A	0.382678	N.A	0.19060	N.A
Urad	0.153167	N.A	N.A	N.A	3.48E-05	N.A	0.099686	N.A	N.A	N.A	N.A	N.A	0.18182	N.A
Moong	0.110828	N.A	N.A	N.A	N.A	N.A	N.A	N.A	0.02423	N.A	N.A	N.A	N.A	N.A
Groundnut	0.033643	N.A	N.A	0.150376	N.A	0.14935	N.A	0.328714	0.42781	N.A	N.A	0.09211	N.A	N.A
Cotton	0.273005	N.A	N.A	0.454956	0.315267	0.20407	0.002912	0.272328	N.A	0.035676	N.A	0.25492	N.A	N.A
Sugarcane	0.229824	N.A	0.121654	N.A	0.269778	N.A	N.A	0.247205	N.A	0.155214	N.A	0.40488	0.00446	N.A
Jute	N.A.	0.50	0.285314	N.A	N.A	N.A	N.A	N.A	N.A	N.A	N.A	N.A	N.A	0.50
Gram	N.A	N.A	N.A	N.A	0.009152	N.A	0.252657	N.A	N.A	N.A	0.041303	N.A	0.17242	N.A

Table A2. Contd.

Mustard	N.A	N.A	N.A	N.A	0.153561	N.A	N.A	N.A	0.11876	N.A	0.102786	N.A	0.16932	N.A
Ragi	N.A	N.A	N.A	N.A	N.A	0.15396	N.A	N.A	N.A	N.A	N.A	N.A	N.A	N.A
Sunflower	N.A	N.A	N.A	N.A	N.A	0.30572	N.A	0.126475	N.A	N.A	N.A	N.A	N.A	N.A
Arhar	N.A	N.A	N.A	N.A	N.A	N.A	0.209356	N.A	N.A	N.A	N.A	N.A	N.A	N.A

The values of weights are square of loadings of first principal component. Source: Author's calculations.

Table A3. Weights of value of machine use per hectare used to drive composite index of capital.

	A.P.	Assam	Bihar	Gujarat	Haryana	Karnataka	M. P.	Maharashtra	Orissa	Punjab	Rajasthan	T. N.	U.P.	W. B.
Paddy	0.186117	0.50	0.263628	N.A.	0.068236	0.219797	0.15674	N.A.	0.386131	0.086585	N.A.	0.279401	0.133968	0.50
Wheat	N.A.	N.A.	0.282988	N.A.	0.093517	N.A.	0.158857	N.A.	N.A.	0.340972	0.125242	N.A.	0.107928	N.A.
Jowar	0.110362	N.A.	N.A.	N.A.	N.A.	0.134187	0.157719	0.212881	N.A.	N.A.	0.135055	N.A.	N.A.	N.A.
Maize	0.06897	N.A.	0.13904	N.A.	N.A.	N.A.	0.140717	N.A.	N.A.	N.A.	0.165976	N.A.	0.052469	N.A.
Bajra	0	N.A.	N.A.	0.337278	0.19959	N.A.	0	N.A.	N.A.	N.A.	0.195572	N.A.	0.151193	N.A.
Urad	0.163114	N.A.	N.A.	N.A.	N.A.	N.A.	0.11793	N.A.	N.A.	N.A.	N.A.	N.A.	0.152819	N.A.
Moong	0.143311	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	0.354716	N.A.	0.193994	N.A.	N.A.	N.A.
Groundnut	0.177013	N.A.	N.A.	0.361624	0	0.185535	N.A.	0.164426	0.259093	N.A.	0.184163	0.233083	0.126163	N.A.
Cotton	0.000112	N.A.	N.A.	0.301099	0.167652	0.200362	0.05526	0.196162	N.A.	0.231472	N.A.	0.23388	N.A.	N.A.
Sugarcane	0.151001	N.A.	0.034368	N.A.	0.128811	0.106553	N.A.	0.21874	N.A.	0.340972	N.A.	0.253636	0.130574	N.A.
Jute	N.A.	0.50	0.279976	N.A.	0	N.A.	N.A.	N.A.	6.08E-05	N.A.	N.A.	N.A.	N.A.	0.50
Gram	N.A.	N.A.	N.A.	N.A.	0.153267	N.A.	0.166144	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
Mustard	N.A.	N.A.	N.A.	N.A.	0.188927	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	0.144885	N.A.
Ragi	N.A.	N.A.	N.A.	N.A.	N.A.	0.153564	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
Sunflower	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	0.20779	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
Arhar	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	0.046632	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.

The values of weights are square of loadings of first principal component. Source**:** Author's calculations.