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# Production efficiency in Indian agriculture: An assessment of the post green revolution years

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ABSTRACT

In this paper we use the nonparametric method of Data Envelopment Analysis (DEA) to obtain Pareto-Koopmans measures of technical efficiency of individual states over the years 1970–71 through 2000–01 in a multi-output, multi-input model of agricultural production. We disaggregate overall efficiency into two distinct components representing output and input efficiencies and identify the contribution of individual outputs and inputs to the measured level of overall efficiency. Because introduction of modern inputs has been a major component of the process of modernization of Indian agriculture, we examine to what extent different states succeeded in utilizing the modern inputs compared to the traditional inputs. Variations in the DEA efficiency scores across states and over years is explained in terms of differences in various institutional and demographic factors in a second stage regression analysis.



## 1. Introduction

Popularly known as the Green Revolution, the new agricultural policy introduced in India in the late 1960s ushered in an era of modernization in the country's traditional agriculture that had changed little from the Colonial days over the first two decades since Independence from British rule in 1947. The main pillars of the Green Revolution were introduction of high yielding varieties (HYV) of wheat and rice, widespread use of chemical fertilizers, introduction of agricultural machinery (like tractors and pump sets), extending irrigation to a greater area under cultivation thereby allowing multiple cropping, and creation of proper institutions for agricultural credit. Success of the Green Revolution is evident from the fact that although deprivation and malnutrition remains an endemic problem in rural areas, India has achieved self-sufficiency in food and is no longer dependent on imports or outright aid from donor countries to feed its population. In a parallel manner, development of the non-food segment of the agricultural sector helps to foster growth of textiles, food processing, and other agro-based manufacturing. Overall, the extent of transformation of Indian agriculture over the first three decades following the Green Revolution is genuinely impressive. One cannot, however, ignore the fact that the index of food grains production in 2002–03 fell by 18.6% from the level reached in the previous year. This was preceded by a 6.66% drop in 2000–01 and followed by a 7.04% drop in 2004–05. One suspects that the Green Revolution is losing its momentum and another major breakthrough would be needed to sustain the growth process. An important objective of this paper is to investigate whether greater productivity is achievable within the limits of the prevalent technology through elimination of technical inefficiencies while Indian agriculture waits for the next major technological breakthrough.

There are numerous studies in the existing literature that measure efficiency in Indian agriculture in the recent period. Most of them used the econometric stochastic frontier analysis. Notable among them are Kalirajan [17] who estimated a profit function for winter rice, Kumbhakar and Bhattacharya [18] who estimated a generalized profit function incorporating price distortions resulting from imperfect market conditions, socio-political and institutional constraints in jute cultivation, Bhattacharya and Kumbhakar [5] who estimated a generalized indirect production function also for jute, and Tadesse and Krishnamoorthy [27] who estimated a stochastic frontier production function for paddy. A notable exception is Sengupta [24,25] who applied three alternative empirical approaches – stochastic frontier analysis, data envelopment analysis, and conventional regression analysis to analyze the same data set from paddy cultivation.

Several of the studies (e.g., Shanmugam and Venkataramani [26]) also have sought to explain the observed variation in technical efficiency in terms of a number of farm characteristics like the farmer's education and experience, contacts with agricultural extension stations, access to credit, and farm size.

Two important points should be noted about the existing studies. First, all of these studies are based on farm level data

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drawn from specific states (or regions within a state) and most of then consider the inputs and output of an individual crop over a relatively short period of time. As such, none of these studies individually nor all of them collectively can be regarded as a long term analysis of production efficiency in agriculture at an All-India level. Second, except for Sengupta [24,25] all of them use some explicit parametric specification of the production (or cost) function as the analytical format.

In this paper we use the nonparametric approach of Data Envelopment Analysis (DEA) to obtain Pareto-Koopmans measures of technical efficiency of individual states in India over the years 1970–71 through 2000–01in a multi-output, multi-input model of agricultural production. The Pareto-Koopmans efficiency measure is a complete measure in the sense that it reflects unrealized potential for increasing any output and decreasing any input that the firm has failed to exploit. Although there are some applications in other areas,[1] to the best of our knowledge, this is the first study measuring Pareto-Koopmans efficiency in agricultural production. The main contributions of our paper can be highlighted as follows:

- Unlike the previous studies cited above, we examine the entire agricultural sector of the country rather than a sample of individual firms from a specific region. In that sense, ours is an analysis at the national level.
- We utilize a panel data set covering three decades following the Green Revolution. This enables us to track how different regions of the country have performed over this period. Because introduction of modern inputs has been a major component of the process of modernization of Indian agriculture, we examine to what extent different states have succeeded in utilizing the modern inputs compared to the traditional inputs.
- In our empirical analysis, we disaggregate the overall efficiency measure into two distinct components representing output and input efficiencies. Further, we are able to identify the contributions of individual outputs and inputs to the measured level of overall efficiency. This permits us to focus separately on the rate of utilization of the modern inputs like agricultural machinery, chemical fertilizers, and power.
- Use of a panel data set covering a long time period permits us to track how input efficiency, output efficiency, and overall technical efficiency has evolved over the years.
- We follow up the first stage DEA with a 2-way fixed effects panel data regression in the second stage trying to explain the observed variation in efficiency across different states and over the years covered by this study.

The rest of the paper is organized as follows. Section 2 provides an overview of the nonparametric methodology. Section 3 describes the data and reports the empirical findings from the efficiency analysis. A statistical analysis of the factors explaining the observed variation in technical efficiency is presented in Section 4. The main conclusions and policy implications are summarized in Section 5.

## 2. The nonparametric methodology

### 2.1. The technology and technical efficiency

Consider an industry producing bundles of $m$ outputs $y$ from bundles of $n$ inputs $x$. The production technology is defined by the production possibility set

$$T = \{(x, y) : y \in R_+^m \text{ can be produced from } x \in R_+^n\}, \tag{1}$$

An input–output bundle $(x^0, y^0)$ is feasible if $(x^0, y^0) \in T$.

The bundle $(x^0, y^0)$ is *weakly efficient* in its *input-orientation* if it is not possible to reduce all inputs simultaneously without reducing any output. That is,

$$(x^0, y^0) \in T \text{ and } \beta < 1 \ \Rightarrow \ (\beta x^0, y^0) \notin T. \tag{2a}$$

Similarly, $(x^0, y^0)$ is *weakly efficient* in its *output-orientation* if

$$(x^0, y^0) \in T \text{ and } \alpha > 1 \ \Rightarrow \ (x^0, \alpha y^0) \notin T. \tag{2b}$$

That is, all outputs cannot be increased simultaneously without increasing any input.

Note that input-oriented weak efficiency does not preclude reduction in one or more (though not all) inputs. Similarly, output-oriented weak efficiency is compatible with increase in one or more individual outputs. Thus, weak efficiency does not imply Pareto efficiency. Both input- and output-oriented weak efficiencies are essentially *radial* in nature because one considers radial contraction of the input bundle or a radial expansion of the output bundle.

By contrast, $(x^0, y^0)$ is *strongly* input-efficient only if a reduction in *any* component of the $x^0$ input bundle would render the output bundle $y^0$ infeasible. That is

$$(x^0, y^0) \in T \text{ and } x \leq x^0 \ \Rightarrow \ (x, y^0) \notin T. \tag{3a}$$

In an analogous manner, $(x^0, y^0)$ is *strongly* output-efficient only if

$$(x^0, y^0) \in T \text{ and } y \geq y^0 \ \Rightarrow \ (x^0, y) \notin T. \tag{3b}$$

Finally, $(x^0, y^0) \in T$ is Pareto-Koopmans efficient if both of the following conditions simultaneously hold:

$$\text{(i) } x \leq x^0 \Rightarrow (x, y^0) \notin T; \tag{4a}$$

and

$$\text{(ii) } y \geq y^0 \Rightarrow (x^0, y) \notin T. \tag{4b}$$

Thus, strong input- and output-efficiency are both necessary and are together sufficient for Pareto-Koopmans efficiency.

Although useful for a summary evaluation of performance, the measured level of weak efficiency (whether input- or output-oriented) fails to provide a proper benchmark for improvement. In order to become fully efficient a firm has to eliminate underproduction of every output and at the same time avoid underutilization of every input. Apart from providing a target input–output bundle that the firm should try to attain, Pareto-Koopmans analysis provides input- and output-specific measures of efficiency.

### 2.2. Data envelopment analysis

In order to calibrate any of the various technical efficiency measures considered above, we need to construct the production possibility set empirically from observed data. In parametric models, one starts with an explicit specification of the production technology in the form of a production function (in the single output case) or a transformation function (in the multiple output case) and uses appropriate statistical methods to obtain estimates of the parameters of the specified function from sample data. By contrast, in the nonparametric approach of Data Envelopment Analysis (DEA) one makes a number of fairly general assumptions about the underlying technology but specifies no explicit functional form. Introduced by Charnes, Cooper, and Rhodes (CCR) [8] and further generalized by Banker, Charnes, and Cooper (BCC) [3], DEA allows one to construct the production possibility set empirically from observed data. Specifically, one makes the following

[1] Ray and Jeon [23] measured the Pareto-Koopmans efficiency of America's top-rated MBA programs.