International Journal of Applied Research 2017; 3(5): 641-645

ISSN Print: 2394-7500
ISSN Online: 2394-5869
Impact Factor: 5.2
IJAR 2017; 3(5): 641-645
www.allresearchjournal.com
Received: 01-03-2017
Accepted: 02-04-2017

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Trends in agricultural productivity: A state level analysis

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Abstract
This paper focuses on total factor productivity in India's Agriculture sector. In order to calculate total factor productivity Malmquist Index has been used. Further total factor productivity has been decomposed into technical change and efficiency change. It has been found that Indian states perform dismally in both these indicators of TFP.

Keywords: Efficiency Change, Data envelopment analysis, Malmquist Index, Total factor productivity, Technical change

Introduction
Agriculture sector is important basically for three reasons i.e. production of grains, provision of employment and maintenance of ecological balance. In Indian context it's important because of high rates of poverty and population growth which raises the mouths to be fed. There exists a negative relationship between agricultural performance and poverty. Farmers suicide each year because of insufficient agricultural income. So in order to eradicate poverty, policy makers should focus on determinants of agricultural productivity as productivity determines the returns. Besides this the period between 2003-2008 has been considered as the "Golden Era" by *Nagraj* since this period experienced phenomenal growth in GDP of around 8.7% which was mainly service sector led and export oriented. This paper is an attempt to look at what all was the determinant of decelerating agricultural productivity during this period so that more inclusive growth can be facilitated. The existing literature on agricultural productivities mainly focuses on partial productivities on account of land and labour (Dev, 1988) [2] which doesn't capture total agricultural productivity and hence are unable to reveal the entire scenario. Second set of literature looks at allocative efficiency which only looks at the fact that inputs are used in the right proportion with respect to their prices. Also some of the researchers use indices like output index and Laspeyer's index to account for productivity changes. This approach has its own limitations since it requires prices and many of the inputs are not widely exchanged (land, labour). Hence in this paper in order the address the issues discussed above we stick to total factor productivity measure of agricultural productivity which can further be decomposed into technical change and technical efficiency. The technique we use here is deterministic non parametric approach using Data Envelopment Analysis. This paper is concerned with identification and interpretation of state level agricultural productivity of some selected Indian states during the period 2004-05 to 2010-11.
The next section presents a short description of existing literature on this topic. Third section deals with methodology used in this paper. Then we have data description followed by estimation in fourth section. Lastly we sum up with conclusion and policy implications.
Literature review Since agriculture sector is of prime importance for a country like India, there have been lots of research in this field. As mentioned in the introduction most of them have been unable to capture the entire aspects of total agricultural productivity. For instance output index has remained one of the favourite measures of productivity for a lot of researchers *(Raymond P Christensen & Herald T. Yee)* calculated as the ratio of total output and total input at constant prices to get the real changes. So what they do is they define total factor productivity as average product of all inputs.

$$TFP = Y/X$$

$$\frac{\partial lnTFP}{\partial lnt} = \frac{\partial lnY}{\partial lnt} - \frac{\partial lnX}{\partial lnt}$$

where X &Y are output and input vectors.

Showed that when the underlying technology can be represented by a Cobb-Douglas production function and where (i) producers maximize profits and (ii) markets are in long-run competitive equilibrium (total revenue equals total cost), then above equation can be written as:

$$ln\left(\frac{TFP_t}{TFP_{t-1}}\right) = \sum\left\{R_i\left(\frac{lnY_{i,t}}{lnY_{i,t-1}}\right)\right\} - \sum\left\{S_j\left(\frac{lnX_{i,t}}{lnX_{i,t-1}}\right)\right\}$$

where R_i is the revenue share of the *i*th output and S_j is the cost share of the *j*th input. A key limitation in using above equation for measuring agricultural productivity change is that we lack data on input cost shares for most states. There is simply no comparable information on input prices, especially for inputs that may not be widely exchanged in the market such as farm land and labour. Also when using an index approach, economists moved from measuring single-factor productivity to measuring multifactor productivity with Laspeyre's, Paasche's, or Fisher's indices. So this accounting methodology which makes use of indices to estimate TFP allowed prices to serve as weights on inputs and outputs but implied a highly restrictive fixed-proportions (CRS) production technology.

Also we have huge literature centred around partial productivity only (Mahendra Dev 1988) [2]. Allocative efficiency too has been chosen by a lot of researchers which doesn't address either the technical efficiency aspect or the technical change aspect of TFP. Besides this most of the research work in this regard in India has made the use of data from Farm Management Survey based on firm level data which is not suited for aggregating over the economy as a whole to bring forth the macro level picture. On the whole we can say that most of the researchers have focussed on parametric approach which either can be used under stochastic frontier approach or deterministic approach. It models the state of technology by including a time trend in the production or cost functions and the partial differentiation with respect to time to get estimates of technological changes. This model assumes best possible frontier which is hypothetical and hence imposes severe restrictions on production technology.

This paper attempts to circumvent the problems discussed above by estimating a distance function, such as a Malmquist index, which measures productivity using data on output and input quantities alone (Coelli and Rao 2005) [4] and hence there is no role of prices. Malmquist index can also be decomposed into technical efficiency change, technical change and scale effect components which can't be estimated by above approaches. Also using LP approach for DEA ensures we make the use of "best" possible technology and hence no restrictions on functional form as in case of parametric approach. Agricultural productivity is the measure of efficiency with which inputs are used in agriculture to produce output. Technical inefficiency been identified as a type of production inefficiency. Technical inefficiencies arise when a firm does not operate on the boundary of its production function. This paper measures technical inefficiencies using DEA and have demonstrated that these inefficiencies are widespread among states. Computation of technical inefficiency has led to several extensions. *Caves et al* developed a productivity index, the Malmquist index, composed of different measures of technical efficiency. *Fare et al* defined a generalized Malmquist productivity index that combines a technical efficiency index with a technical change index. They also demonstrated the relationship between technical inefficiencies and Debreu's concept of a distance function. This paper provides estimates of technical efficiency and productivity of the agricultural sector for six states using data from Indiastat.com. The empirical section provides state-wide estimates of indices that measure the efficiency of agricultural resource use (technical efficiency) and the impact of technical change on agricultural productivity for the agricultural sector.

Methodology

Agricultural Productivity has been defined by several scholars with reference to their own views and disciplines. Agriculturalists, agronomists, economists and geographers have interpreted it in different ways. Agricultural productivity is defined in agricultural geography as well as in economics as "*output per unit of input*", and the improvement in agricultural productivity is generally considered to be the results of a more efficient use of the factors of production, viz. physical, socioeconomic, institutional and technological. Here we concentrate on technical efficiency and technical change measure using Malmquist indices based on distance functions for different states. The Malmquist index has several features, which makes it an attractive approach. First, it is a TFP index (Fare and Primont, 1995) [3]. Second, it can be constructed using distance functions, which are primal measures based only on input and output quantities rather than price. Third, the index can be decomposed into technical efficiency change, technical change and scale effect components. Efficiency change can be further decomposed into pure efficiency change and scale components. To measure TFP in state agriculture, Malmquist index uses non-parametric linear programming (LP). The LP approach has two advantages over the econometric one in measuring productivity change. First, it compares the states to the "best" practice technology rather than "average" practice technology. Second, it does not require the specification of an ad-hoc functional form. We use linear programming techniques to construct the Malmquist productivity index using Data Envelopment Analysis for the selected states of India. Our analysis is confined to the measurement of TFP growth in agricultural sector, which is decomposed into efficiency and technological changes with an isoquant serving as the reference technology. Data envelopment analysis (DEA) was introduced by *Charnes et al* as a way to establish a best practice frontier without imposing restrictions on production technology. *Seiford and Thrall* argue that DEA is a methodology directed to frontiers rather than central tendencies. The distance from a frontier calculated by DEA and one particular observation provides a measure of *Farrell's technical efficiency. Fare* shows that this estimate of technical efficiency represents the inverse of the distance function. *Chambers et al* show that DEA can estimate each distance function used in the Malmquist index. One key feature to DEA is its generality. Reference technology levels for each input and output are defined by a linear combination of sample observations on each input and a linear combination of sample observations on each output. Restrictions inherent in assuming specific production functions are avoided as it's based on best possible frontier with simple restriction that all other decision making units (DMUs) lie on or below the frontier. Formal analysis of DEA is discussed below.

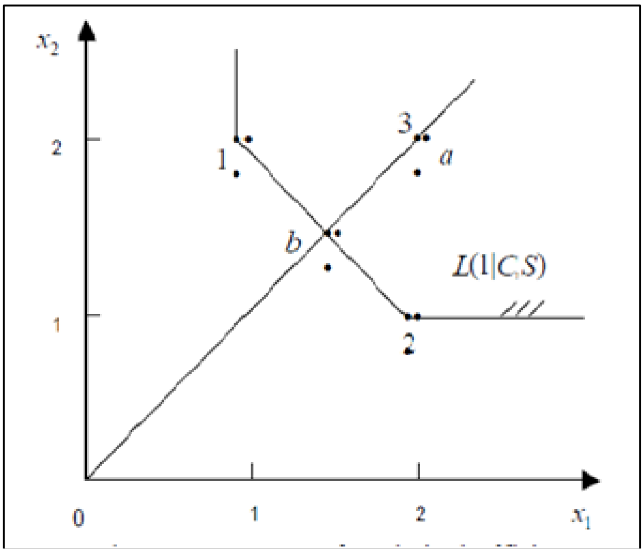
There are K DMUs which produce m outputs $(y_1, y_2, y_3, y_4, y_5, \ldots\ldots, y_m)$ using n inputs $(x_1, x_2, x_3, x_4, x_5, \ldots\ldots, x_n)$. The input requirement set can be written as:

$$L(Y|C,S) = \left\{ \begin{array}{c} x_1, x_2, x_3, x_4, x_5, \ldots\ldots, x_n : \\ \sum_{k=1}^{K} z_k\, y_{km} \geq y_m \text{ ; m} = 1,2, \ldots\ldots\ldots \text{M} \\ \sum_{k=1}^{K} z_k\, x_{kn} \leq x_n; \text{ n} = 1,2, \ldots\ldots\ldots, \text{N} \\ \\ z_k \geq 0; k = 1,2,3, \ldots\ldots\ldots, K \end{array} \right\}$$

z_k is referred as intensity variable here and hence weights on each specific cross sectional observation. The production technology consists of reference outputs and reference inputs. The reference outputs are defined by a linear combination of outputs across k cross-sectional observations (the right-hand side of the first M constraints).The reference inputs are defined by a linear combination of inputs across k cross sectional observations (the left-hand side of the ensuing N constraints). Technology is defined such that (1) the level of the m^{th} output is less than or equal to a reference output, and (2) the level of the n^{th} input is greater than or equal to a reference input. The combination of each output and each input across all K observations forms a series of line segments that specifies the boundary of the technology set. When there is one output and two inputs, the boundary of the input requirement set defines an isoquant. The weights on the outputs and inputs (z_k) must be non-negative. If an additional requirement; z_k z = 1, is imposed, the boundary of the technology set will be represented as a convex combination of outputs and inputs across all K observations.

Figure 1 presents hypothetical data representing three DMUs that use two variable inputs (x1, x2) to produce one output y. The boundary line L(1, C, S) connecting the efficient observations represents a convex combination of relevant outputs and inputs. This boundary line is the "reference isoquant”. The efficiency measures discussed here are a part of profit maximisation namely cost minimisation. Efficiency requires production of given level of output using fewest inputs possible (hence cost saving). Firm 1 and 2 are on the boundary of input requirement set whereas firm 3 lies inside the isoquant. So firms 1&2 are reference firms and hence efficient firms while firm 3 is inefficient. Here firm 3 can scale down it's input use from point 'a' to point 'b' such that technical efficiency is represented as oa/ob. This input saving measure is referred to as *Farell's input* distance function formally written as:

$$F_i(y, x|c, s) = Min\{\gamma : \gamma x \in L(y, x)\}$$



The above programming problem finds the minimum value of X such that both output and input for the specific observation k lie within the input requirement set. The value of γ in this problem is an estimated index of technical efficiency, relative to the best-practice frontier for observation k. This value of γ represents the inverse of the value of the distance function *(Shepherd's input distance function*, when it is 1;represents multi input multi output production frontier*)* for observation k. Subtracting γ from 1 gives the largest proportional reduction in inputs that can be achieved without reducing output. The programming problem also calculates the z terms (the weights on the inputs and outputs) by calculating the piecewise linear convex combination of outputs and inputs across all K observation.

In order to estimate the Malmquist from period t to t +1, we need distance function for the two periods. We use input saving measure of Malmquist index in our work which is given by:

$$M_t\,(x^{t+1}, y^{t+1}, x^t, y^t) = \left(\frac{D_t^{t+1}(y^{t+1}, x^{t+1}|C,S)}{D_t^{t+1}(y^t, x^t|C,S)}\ \frac{D_t^{t}(y^{t+1}, x^{t+1}|C,S)}{D_t^{t}(y^t, x^t|C,S)} \right)^{1/2}$$

M_i is the product of Efficiency change (EC) and Technical change (TC). Since we stick to input saving measure of malmquist index, its value above 1 represents inefficiency (Regression in productivity). For example If M_i =1.45 then it means productivity has deteriorated by 45% between the two years. Similarly we can interpret EC & TC. Here the reference technology is based on the most conservative use of inputs.

Data Description & Estimation

Data

Data that we have taken for estimation is a panel data set for six selected states (Uttar Pradesh, Punjab, Haryana, Jammu & Kashmir, Himachal Pradesh, Rajasthan) over the period 2004-05 to 2010-11.Data set contains value of agricultural outputs at state level; output in value terms captures relative weightage of different crops. Besides this we have input data on consumption of fertilisers (Urea, DP, MOP). We have taken the average of these three types of fertilisers. The consumption of fertilisers is in '000 tonnes. Then we have data on area as area under crops in '000 hectares. Finally we have data on irrigation as area irrigated in '000 hectares. We have taken only three inputs to account for agriculture output due to data limitation. Value of output at current prices for all the corresponding years have been taken from the website of Ministry of Stats and Program Implementation. Secondly other relevant data on inputs have been taken from indiastat.com. In order to calculate the malmquist index we have created separate sheets of cross sectional data for each period and analysed the productivity change between the adjacent periods. The result thrown up by "onfront", a software that deals with DEA contains columns for EC, TC, F11, F12, F21 & F22.

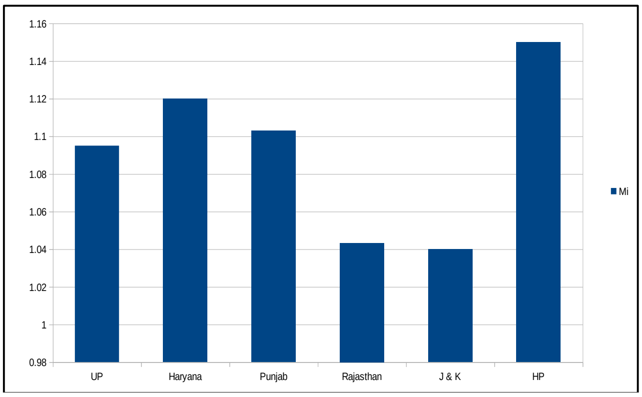
Insights from data: UP being the state with larger area as the largest value of output as well as input consumption as evident from cross sectional data for each year. But this does not say anything about the productivity of U.P. Secondly H.P. has the lowest value of output among all along with lower input consumption. This reflects the agricultural backwardness of the region due to infrastructural bottlenecks on account of difficult terrain. Intensity of use of inputs can be reflected from the ratio of fertiliser application per unit of area under crops and ratio of irrigated area per unit of cropped area.

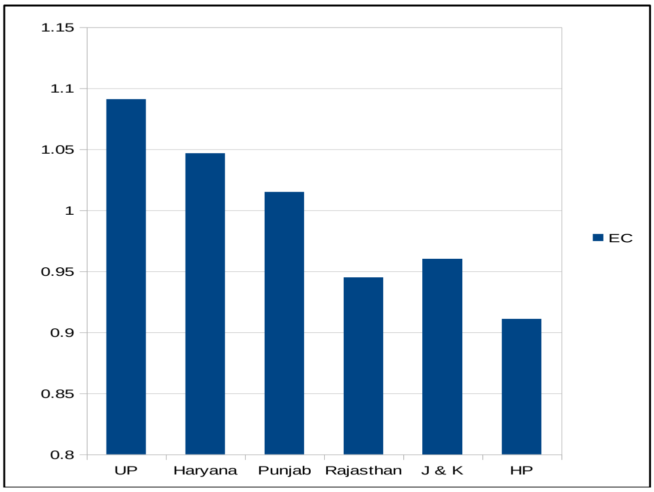
Estimation

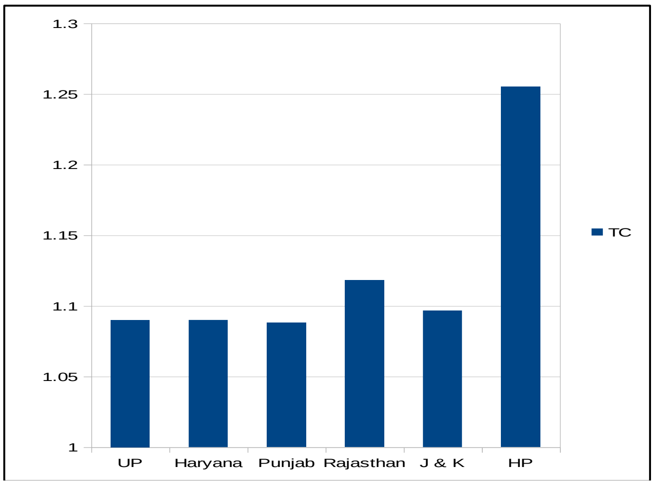
In order to analyse the results we have calculated average value of productivity components (M_i, EC, TC) over the years for all six states and graphed it (M_i, EC & TC on y axis and states on x axis).This facilitates comparison of different productivity indices among states. Next we have calculated average values of M_i, EC & TC each year for all Indian states considered, to facilitate comparison of indices over time.

Intuition

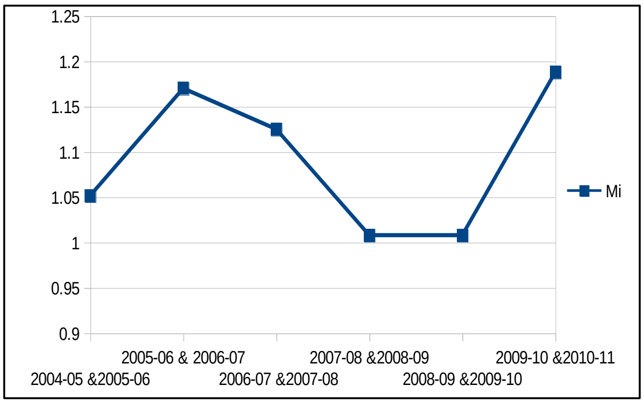
The values of M_i for all the states has remained above 1 indicating regressive productivity change which is consistent with overall declining trend in agricultural productivity. UP has M_i=1.095 that means 9.5% decline in productivity; because of both decline in EC & TC as evident from graphs of EC and TC that shows more than unity values. This imply there has been technical regression and inability to adopt better technology or managerial inefficiency. So here the govt should focus on innovation and incentivize the farmers to adopt existing better technology. H.P. has the largest decline in TFP with M_i=1.15 on account of technical regression which outweighs the improvement in efficiency change. That means here the prime focus should be innovation in R & D so that technical improvement is possible.

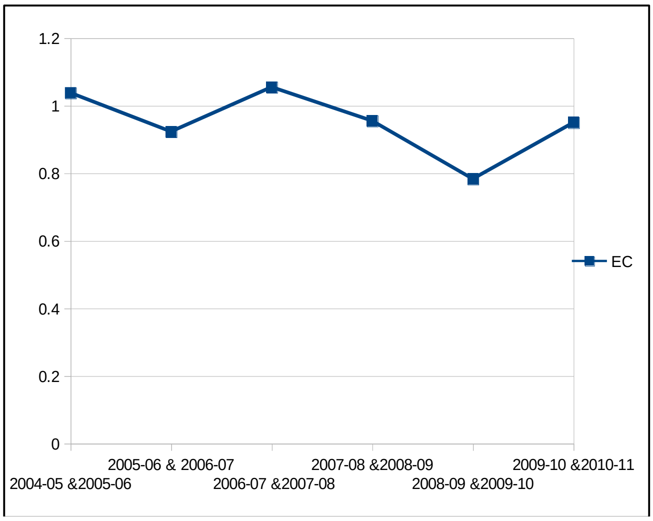


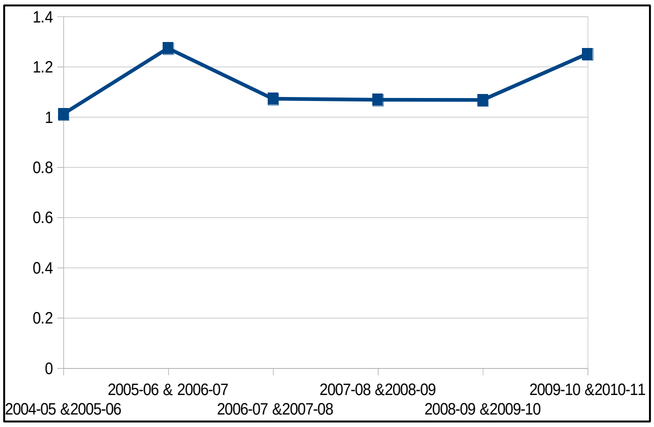




In the same manner we have looked at average productivity components of all six states in each year and shown it graphically. Again this helps in visualisation of trend of productivity and it's components over the years. Time trend too has values of M_i above 1 and hence TFP has declined over the years which complies with above analysis of state wise decline in agricultural productivity. TC remains constantly above 1 whereas EC improves in some years. During 2005-06 Mi=1.05 which suggests decline in productivity by 5%.TC=1 imply no innovation. So the decline in productivity is because of decline in efficiency (since EC is above 1).2008-09 has lowest value of Mi=1.01 implying 1% decline in productivity. Regressive TC and constant EC is observed for the same year. So during these years relatively productivity decline was the minimum. This could be because this period has been termed as 'recovery' period.







Conclusion & Policy Implications

India's agriculture is currently at crossroads where reversing its decelerating growth is a major challenge. Our empirical analysis shows that agricultural productivity has declined overall whether taken state wise or over the years as a whole and the increase in O/P that we observe is merely because of intensive use of inputs (farmers distress). Mechanization of agriculture can result in better use of scarce inputs. Those farmers who adopt new technology can improve their welfare and those who don't and are not productive enough are driven out to seek success elsewhere and sometimes even suicide. Farmers suicide primarily because of erosion of farm income which is actually one of the outcomes of regressive productivity change. The figures for farmers suicide reported by NCEB (National Crime Reports Bureau) was around 18000 in 2004 is alarming. Govt instead of providing relief packages later should take steps to prevent it as life is priceless and it will only add to their budget expenditure. Besides when Total Factor Productivity improves it reduces the producer's cost and brings down the prices thereby stabilising it. Hence the gains get disbursed to both the producers as well as consumers. Those states that have regressive TC like H.P. should focus on innovation since innovation is the key to development and hence invest in R & D. States where both technical regression and inefficiency is experienced should focus on both the parameters. Ex-if a new variety of seed is developed that requires least amount of water; it can save input cost and hence technical change here enables gain in TFP. Innovation in solar plants can lead to provision of cheaper electricity and hence bring down input costs reviving productivity. Subsidised fertilisers, HYV seeds etc by govt can help in adoption of an existing technology and hence facilitate movement towards the 'best' practice isoquant. Also TFP can be improved by investment in irrigation and improvement in infrastructure. Literacy has positive impact on productivity growth and hence should be focussed.

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