Measurement and Determinants of Technical Efficiency in Crop Production: A Review

Isha Sharma, M.K. Sekhon

ABSTRACT
Output is determined by the efficiency with which available technologies are used i.e. with the improvement in technical efficiency. There are extensive numbers of studies focusing on efficiency as a means of fostering agriculture production. The article reviews the literature devoted to technical efficiency analysis in various countries and its applications to agricultural production. The studies reviewed focused particularly on rice and wheat making them the most studied agricultural product by researchers. The review of efficiency analysis shows that agricultural output can be increased without additional inputs with given existing technology. Technical efficiency of agricultural crops like wheat, paddy, cotton etc grown in different countries of the world like India, Pakistan, Ethiopia, Sri Lanka were reviewed and it was found that except for farm size, the variables like farmer education and experience, contacts with extension personnel and access to credit, tend to have a positive and statistically significant impact on technical efficiency.

Key words: Data envelopment analysis, Inefficiency, Stochastic frontier analysis, Technical efficiency.

Enhancement of farm output and income by taking up new technologies has received particular importance as a means to accelerate economic development (Kuznets, 1966; Hayami and Ruttan, 1965). However, output growth is also determined by the efficiency with which available technologies are used (Nishimizu and Page, 1982). Productivity growth can be achieved by improvement in technical efficiency (TE). The increase in TE opens up the prospect for farmers to increase output using the same level of resources (Beltran-Esteve and Reig-Martinez, 2014).

Inefficiency in crop production is one of the major factors obstructing the full exploitation of available innovated technologies in the developing countries (Bravo-Vrata and Evenson, 1994; Jayaram et al., 1992; Taylar and Shonkwiler, 1986; Ali and Flinn, 1989; Kalirajan and Shand, 1989; Arindam, 1994). Inefficiency, to realize the best possible output, is influenced by various socioeconomic factors that get in the way of the decision-making process of a farmer (Dawson, 1985; Kalirajan and Shand, 1989; Kalaitzandonakes et al., 1992).

The increase in production is achievable only through enhancement in productivity, which can be increased through one or a combination of factors, namely, technology, the quantities and types of resources used and their efficiency. Of the various determinants, improvement in the efficiency of resources already available with the farmers is of great concern (Goyal et al., 2006) and widely recognized by researchers and policy makers alike (Arsalanbod, 2005). An underlying premise behind efficiency estimation is that, if the farmers are not using the available technology efficiently, their efforts designed to perk up the efficiency would be more cost-effective than introducing new technologies as a means of augmenting agricultural output (Bravo-ureta and Evenson, 1994).

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Farm production and productivity can possibly be raised (1) by allocating more area for production, (2) by developing and adopting new technologies and/or (3) by utilizing the available resources more efficiently (Ahmed et al., 2013). Deciding for the first method would mean trying to boost output by bringing marginal areas into cultivation. The second method requires the introduction of new technologies which is a long-term process and requires capital. Rather, efficient utilization of available resources is the best way of increasing production especially in the short run (Wudineh and Endrias, 2016). As the resources are scarce it is becoming increasingly important to use these resources at the optimum level which can be determined by efficiency studies.

The purpose of this article is to review the literature dealing with farm level efficiency in developing countries and to appraise the efficiency measures reported in the literature for a wide range of developing countries along with analyses that have sought to explain efficiency variation across farms. These studies benefit economies by determining the extent to which it is possible to lift productivity by optimally using the existing resource.
Measurement of technical efficiency

Frontier function methodology

To measure economic efficiency and to decompose it into technical and allocative efficiency frontier function model introduced by Farrell (1957) was used. In this model, technical efficiency (TE) is defined as the firm’s ability to produce maximum output from the given set of inputs and technology. TE is different from technological change, where the latter reflects an upward shift of the production function or a descending of the unit isoquant. Allocative (or price) efficiency (AE) measures the firm’s ability in selecting the optimal input proportions, i.e., where the ratio of marginal products for each pair of inputs is equivalent to the ratio of their market prices. According to Farrell, economic efficiency is a measure of overall performance and is equal to TE times AE (i.e., EE = TE x AE).

Technical efficiency can either be output or input-oriented. An output-oriented technical efficiency occurs when the greatest amount of output is obtained from a given set of inputs while an input-oriented technical efficiency occurs when a small amount of inputs are required to produce a given level of output (Farrell, 1957).

The frontier models are classified into parametric and nonparametric based on Farrell’s work. Parametric frontiers rely on a specific functional form while non-parametric frontiers do not. Timmer introduced the probabilistic frontier production model and projected a series of frontier production functions by dropping the extreme observations at each stage. This process goes on till the rate of change of the parameter estimates stabilizes. Estimators obtained by these deterministic programming approaches have undefined statistical properties (Bravo-Ureta and Pinheiro, 1997). The deterministic parametric approach was initiated by Aigner and Chu (1968), who estimated a Cobb-Douglas production frontier through linear and quadratic programming techniques. Another deterministic parametric model is the statistical production frontier proposed by Afriat (1972), in which one-sided disturbance term measures the technical efficiency. Maximum likelihood method is used for the estimation of the frontier when explicit assumptions for the distribution of the disturbance term are introduced and in the absence of assumptions the frontier can be estimated by the corrected ordinary least squares method (COLS), Shapiro and Muller (1983), Ali and Chaudry (1990), Ekanayake and Jayasuriya (1987) used deterministic production frontiers to calculate Technical Efficiency (TE). Table 1 shows the studies which used deterministic production frontiers to calculate Technical Efficiency (TE).

Stochastic frontier production

The modeling, estimation and application of stochastic frontier production function to economic analysis assumed prominence in econometrics and applied economic analysis following Farrell’s (1957) seminal paper, where he introduced a methodology to measure the TE, AE and EE of a firm. However, over the years, Farrell’s methodology had been applied widely, while undergoing many modifications and improvements; and one such improvement is the development of stochastic frontier model which facilitates the computation of firm level technical and economic efficiency using maximum likelihood estimate. The Maximum Likelihood Estimation (MLE) can provide the estimates of the stochastic frontier production equation (Shanmugam and Venkataramani, 2006).

(Aigner et al., 1977) and (Meeusen and Van de Broeck, 1977) were the first to propose stochastic frontier production function and since then many changes had been made to stochastic frontier analysis. Stochastic frontier functions enable the researcher to measure both the technical efficiency sources and impact of measurement errors or factors that are not directly related with production process itself (Kolawolen, 2006). The estimated function appears as a frontier or benchmark with the parameter estimates indicating whether the enterprise or production unit is producing at the production or profit frontier (Lengemeier and Lano, 1999).

Data envelopment analysis (DEA)

Data Envelopment Analysis (DEA) is a non-parametric linear programming (LP) approach, used in the estimation of technical, allocative, economic and scale efficiencies of farms. In this method scale and technical efficiency can be disaggregated by sole incorporation of input and output quantities, providing the researcher with relative shares of each source in the inefficiency produced (Gilligan D O, 1998).

With the assumption of constant returns to scale (CRS), the DEA V2.1 computer programme can be employed to estimate overall efficiencies. According to (Coelli et al., 2005), the constant returns to scale (CRS) DEA model is only suitable when the farm is operating at an optimal scale. Some factors such as imperfect competition, financial constraints, etc. may not allow a farm to operate optimally. To capture this possibility (Banker et al., 1984) introduced the Variable Returns to Scale (VRS) DEA model.

Empirical estimates of technical efficiency

Mean Technical Efficiency (MTE) value of various farm products at national and international levels measured by various authors, is given in Table 2. To gather this data, firstly, journals related to economics of crop production were identified and searched. Secondly, various publishers’ websites and databases were covered. Databases included
### Determinants of technical efficiency of crop production

The focus of this review is to provide an empirical evidence of the determinants of productivity variability/inefficiency gaps among farmers. Having knowledge that farmers are technically inefficient might not be useful unless the sources of the inefficiency are identified.

Among factors hypothesized to determine the level of technical efficiencies, education, livestock holding, extension contact, farmers training, cultivated area and participation to irrigation were found to determine technical efficiencies of farmers positively while social status had negative relationship with technical efficiency (Ahmed et al., 2013). According to Wudineh and Endrias et al. (2016) education improves the ability of the household to make informed decision about production inputs. Educated farmers more often have better access to agricultural information and higher tendency to adopt and utilize improved inputs (like fertilizers and crop varieties) more optimally and efficiently (Endrias et al., 2013; Yami et al., 2010; Asefa 2012). Bloom and Canning (2000) point out, health is a factor that positively influences the economic performance through enhancing labour productivity and returns to education. Health status was found to be one of the determinants of efficiency in addition to education, land holding, agroclimatic zone, etc. by Shanmugam and Venkataramani (2006). Cross-country and micro level evidences clearly indicate that health significantly influences economic performance (Barro and Canning, 2000).

Inefficiency is not just a result of the amount of inputs used but factors such as the timing of fertilization, other cultural practices and exogenous factors such as age/sex, also affect efficiency (Fernandez and Nuthall, 2012). The strong positive effect of experience on efficiency implies that learning-by-doing would likely be important as newer, more productive technology becomes available. In a profit inefficiency analysis of vegetable producers of Samsun province between 2002 and 2003, the reasons for inefficiency were analyzed. In this study, education, experience, credit use opportunities, women participation to farm activities and level of knowledge were found as determinants of technical inefficiency (Bozoglu and Ceyhan, 2006). Overall in the Punjab state, education and experience of the family-head, percentage area under the wheat to the total operational area and farm size had significant impact on improving the efficiency in wheat and other crop production. The negative and significant coefficient of education and proportion of area under the wheat to the total operational area and farm size had significant impact on improving the efficiency in wheat and other crop production. The negative and significant coefficient of education and proportion of area under the wheat to the total operational area and farm size had significant impact on improving the efficiency in wheat and other crop production. The negative and significant coefficient of education and proportion of area under the wheat to the total operational area and farm size had significant impact on improving the efficiency in wheat and other crop production. The negative and significant coefficient of education and proportion of area under the wheat to the total operational area and farm size had significant impact on improving the efficiency in wheat and other crop production. The negative and significant coefficient of education and proportion of area under the wheat to the total operational area and farm size had significant impact on improving the efficiency in wheat and other crop production. The negative and significant coefficient of education and proportion of area under the wheat to the total operational area and farm size had significant impact on improving the efficiency in wheat and other crop production.

### Table 2: Mean Technical Efficiency (MTE) value of various farm products

| National | Author(s) | Product | Year | MTE value |
|----------|-----------|---------|------|-----------|
| Farm     | Farm      | 0.80    | 2003 | 0.72      |
| Farm     | Farm      | 0.76    | 2006 | 0.79      |
| Farm     | Farm      | 0.70    | 2008 | 0.85      |
| Farm     | Farm      | 0.80    | 2010 | 0.86      |
| Farm     | Farm      | 0.77    | 2010 | 0.79      |
| Farm     | Farm      | 0.85    | 2012 | 0.88      |

*Note: Authors are cited for cross-reference.*
Baksh et al. (2006) found that age has a negative effect upon the technical efficiency effects in potato production showing that as age of potato growers increases, technical inefficiency declines. This result is supported by Coelli and Battese (1996) who concluded that older farmers have more farming experience and hence have less efficiency. The coefficient of contact with extension staff is positively related with technical efficiency in potato cultivation. This result is in line of Bravo-Ureta and Evenson (1994), Bravo-Ureta and Pinheiro (1997) and Ahmed et al. (1999). According to Bashir (2016) off farm income has positive and significant influence on technical inefficiency. This implied that, farmers who participated in off-farm work were likely to be less efficient in farming as they share their time between farming and other income-generating activities. Productivity suffers when any part of production is neglected. Many farmers employed in activities related with off-farm production and the majority neglect weeding of their wheat crop. Squires and Tabor (1991) used a translog stochastic production frontier, estimated by maximum likelihood procedures, to measure crop-specific technical efficiency in Indonesian agriculture. The mean TE estimates for Java rice, off-Java rice, cassava, peanuts and mung beans were 69%, 70%, 57%, 68% and 55%, respectively, the studied concluded that TE is not significantly related to farm size.

From the study on estimating the level of efficiency in milk production in Tamil Nadu using stochastic frontier production function, it could be concluded that the mean technical efficiency of Kanchipuram, Erode, Nagapattinam and Thoothukudi districts of Tamil Nadu indicated that on an average the sample farmers tended to realise 77.4 to 85.8 per cent of their technical abilities. The reason for this range of technical efficiency was the difference in managerial practices, ease of comprehensive technology, availability of adequate feed inputs in the region and the use of family labour for dairy enterprise (Pandian et al., 2012).

CONCLUSION AND RECOMMENDATION

The majority of the studies reviewed in this paper focused on paddy and wheat crop, making them the most studied agricultural product by researchers. The review of efficiency analysis shows that the mean technical efficiencies were not operating at the possibility production frontier and productivity of crops can be improved with the efficient use of present technologies and inputs which are at the disposal of farmers and without requiring the introduction of new technologies.

The area under crop, access to markets; access to extension service related to crop production; use of fertilizer and improved seed varieties, education, farm income and age are some significant determinants of efficiency. This finding, has been widely reported in many policy research, which indicates that agricultural productivity is widely influenced by these factors. Consistent efforts to improve farmers’ access to technical information and product markets are required to restore the productivity of farmers.

Improvement in the yield can be attained not only by improving technical efficiency but by enhancing overall economic efficiency which suggests that added efforts should be devoted to investigate the impact of both allocative and technical efficiency on performance. The fact that output can be augmented by making efficient utilization of the inputs which are at the disposal of the farmers, does not mean that the researchers should ignore the development of the new technology.

This study reported that the limited number of farm size and efficiency studies have been conducted and the researchers should focus on this as it is likely to play an imperative part in the public policy arena in many developing countries.

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