

## A Review of Literature on Productive Efficiency in Agricultural Production

<sup>1</sup>Burhan Ozkan, R. Figen Ceylan, Hatice Kizilay

Akdeniz University, Faculty of Agriculture, Department of Agricultural Economics

---

**Abstract:** It is not possible to receive identical yields with utilisation of completely equal amount and quality of inputs. There are discrepancies between production amount and production values, amounts and values of inputs used and profit ratios of enterprises, even if the enterprises have identical technological constraints. This depends upon different productive capabilities and less favourable utilisation resources by some enterprises. Productive efficiency or economic efficiency is determined as production of maximum amount of outputs by utilising minimum amount of inputs under a given technological structure. Yet, the determinants of productive efficiency are related with the production process and allocation of resources. The aim of this paper is to review the recent literature devoted to technical efficiency analysis, which is related to the technical process, and its applications to agricultural production, which has a complex input structure compared to industrial production.

**Keywords:** Productive Efficiency, Technical Efficiency, Allocation of Resources, Stochastic Frontier, Agriculture.

---

### INTRODUCTION

Measurement of success in agricultural production depends on proper interpretation of cost and revenue structures of enterprises. In this interpretation, financial success can be attributed to enterprises of which the revenues exceed costs. Yet, whether the accounting profits of enterprise is adequate to acknowledge an enterprise as successful is controversial. The enterprises utilise various inputs for production. However, the outcome of input processing is not directly related with the amount and cost of inputs. It is the technical process affecting the final output. Two identical firms having identical input structures may end up with differentiated yields or different cost-revenue structures. Therefore, it is also possible to find out that an enterprise having accounting profits is not efficiently utilising the inputs incorporated or an enterprise which has a negative profit scheme is implementing the best bunch of activities possible.

However, the evaluation of success of the enterprise in terms of effective use of inputs (land, labour, seeds, chemicals, water, energy, etc for vegetative production) and maintenance of a sound cost structure lies in the efficiency analysis of the process. There are various methodologies utilised in order to evaluate the efficiency of a production system, in our case agricultural production. Most of them stem from the initial efficiency studies conducted by Michael Farrel in 1957. Farrel described productive efficiency

as production of a well-defined good with minimum costs under a predetermined technological constraint <sup>[21]</sup>. This early definition yielded diversification of different measures of efficiency. This paper is constructed to review different technical efficiency measures developed and recent literature on these measures, followed by exemplary implementation of methodologies to agriculture. Interpretation of efficiency in agriculture is also as important as the evaluation of agricultural outputs with respect to diverse range of inputs used has been considered as a critical task within the literature. In this sense the following sections provide a review of efficiency measures and how technical efficiency is calculated and recent studies stemming from different methodologies utilised in the field of agriculture.

**Efficiency Measures in the Literature:** It is not possible to receive identical yields with utilisation of completely equal amount and quality of inputs. There are discrepancies between production amount and production values, amounts and values of inputs used and profit ratios of enterprises. These discrepancies, pointing to different level of productive efficiency of enterprises, stem from different technical qualifications and less favourable utilisation of resources <sup>[22]</sup>.

The agricultural enterprises or farms, which have productive efficiency, provide opportunities for farmers to produce more farm income, which leads to a rise in the welfare level of farm workers <sup>[11]</sup>. Accordingly, the

productive or economic efficiency of the enterprise is rather crucial for agricultural holdings, as it is for industrial enterprises. The productive efficiency of the farm is a blend of input-output relations explaining the farm level price discrepancies and enabling strategic planning for production<sup>[17]</sup>. In accordance, technical efficiency analysis is aggregated and applied to agricultural production, which embraces a mixed input-output structure comparing to industrial production.

Michael Farrel tested the productive efficiency under physical efficiency of input-output transformation and price efficiency indicating optimal use of resources<sup>[21]</sup>. The first part of efficiency referring to technical efficiency means production of maximum amount of output with incorporation of minimum possible amount of inputs<sup>[29,8]</sup>. The resource allocation efficiency, on the other hand, is determination of the optimal output set in response to the given input prices and proper interpretation of overall macroeconomic and microeconomic situation accordingly<sup>[18,10,29,27]</sup>.

For achieving productive efficiency, having technical and resource-allocation efficiencies is a must for an enterprise, yet these significances are not solely adequate for productive efficiency. This means that an enterprise can have the best amount of output in exchange of utilisation of best priced, minimum amount of inputs, but this characteristics may not be enough for productive or economic efficiency<sup>[29,1]</sup>.

According to Farrel's interpretation of technical efficiency it is not feasible to produce by using more inputs than required while valuing these inputs more than the market values. Yet, it is also not efficient to use more inputs than required even if they are priced as the market values. Therefore, the technical inefficiency is defined by Farrel as the ratio of the least possible (best) amount of inputs to be used to actual amount of inputs used for a given amount of output<sup>[21]</sup>. The ratio ranges between 0 and 1 and, the least the ratio means that less ineffective is the production process. Yet, the resource allocation inefficiency is the ratio of input prices rated in the market to the prices paid by the producer and it is interpreted in a similar way the technical inefficiency. Therefore, the productive inefficiency, which is an index ranging between 0 and 1 in this scenario, is obtained by multiplication of technical and resource-allocation inefficiency indices<sup>[21,29,27]</sup>.

With this interpretation, Farrel achieved one more thing. He disaggregated technical and resource-allocation inefficiencies. By this disaggregation, it became possible to assess technical efficiency of production and to make projections for policy purposes. Technical efficiency can be measured through three different methodologies, respectively parametric and

non-parametric approaches and productivity indices depended on growth accounting measures<sup>[19]</sup>. These approaches are interpreted in details below.

#### **Non-parametric Methods and Growth Accounting:**

Non-parametric methods of measuring productive inefficiency are broadly speaking dependent upon classification of quantitative and qualitative variables under the well known methodology of Data Envelopment Analysis (DEA). In this analysis disaggregation of scale and technical efficiency by solely incorporation of input and output quantities is possible, which provides the researcher with relative shares of each source in the inefficiency produced<sup>[15]</sup>. The linear programming of inputs and outputs in terms of quantity used and quantity produced also leads inferences for multiple inputs and outputs simultaneously<sup>[19]</sup>. The DEA methodology produces a distance function which refers to the distance of inputs (quantities) utilised and outputs (quantities) obtained to a benchmark input and output set, and specific inference for single inputs is possible.

The other approach developed to measure the technical efficiency is the partial productivity indices developed to indicate the ratio between the inputs and outputs. It is possible to measure the impact of single or multiple inputs on the total amount of production by productivity indices developed in accordance with the concept of growth accounting. The efficiency scale is the unique comparison of the amount of input and the output in a single input case. Yet, the impact can be measured partially for multi-input cases<sup>[3]</sup>. In the multi-input case, the inputs other than the one being considered are taken as constant for a specific time of measurement for static scaling. Yet, the growth in time in such cases can be managed by dynamic indexation<sup>[25]</sup>. However, partial productivity interpretations do not allow proper sample and/or enterprise based technical efficiency interpretations or sample wise comparisons. The variation in partial productivity indices can hardly be attributed to the variation in productive (or economic) efficiency<sup>[3]</sup>.

## **MATERIAL AND METHODS**

Parametric methods devoted for measurement of technical efficiency are structured based on a parameterized production, cost or profit function and establishment of a benchmark for interpretation of the whole sample in terms of efficiency. The process executed is estimation of the quantitative impacts of parameters – resources on the production quantity – value, cost value or profit value. The interpretation of the function (production-cost-profit) can be in descriptive, observable or stochastic, probable manner.

**Descriptive Methods:** The function of the case is estimated in a closed manner and the all estimation error is attributed to technical inefficiency regardless of it being emerged due to a production-free inefficiency or a probabilistic influence <sup>[10]</sup>. Therefore, the frontier or the benchmark function is either mathematically programmed considering the inputs and outputs or estimated statistically by using Ordinary Least Squares (OLS) without considering stochastic variation <sup>[29,19]</sup>. These descriptive models, excluding stochastic variation in the error term are generally preferred in order to receive irrevocable interpretation opportunities for technical inefficiency. However, it is not possible to interpret the efficiency with reference to enterprises taking place in the sample and accordingly, only the sample average of the technical efficiency can be computed <sup>[21]</sup>. Yet, there is a high probability for low determinative power of these models in terms of estimating efficiency and causes of efficiency as they are structured to restrict the estimation errors <sup>[29]</sup>.

**Stochastic Methods:** The parameterised stochastic frontier function both embraces technical inefficiencies of the production process and the probabilistic, random effects leading to productive inefficiency. In this sense, there appears a composite error term involving technical inefficiency and random effects <sup>[21]</sup>. Therefore, 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 <sup>[19]</sup>. 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 <sup>[23]</sup>.

Within the estimation methodology, the benchmark for the production or profit, which also embraces the cost, is obtained by the statistically significant parameter estimates and mean values of the variables. The next step is to measure the distance between the observed dependent variable and the benchmark value. This quantitative distance provides the value of technical inefficiency when random effects are disaggregated from the estimated composite error term <sup>[4,21]</sup>. As the composite error term involves probabilistic outlier effects as well as the attributes of technical inefficiency, the out or in shifts from the frontier can be observed across enterprises. In order to disaggregate the effects of the random shocks, which refer to stochastic changes in the frontier across observation units rather than direct shifts in the frontier, it is assumed that the stochastic part of the error term follows a bi-directional normal distribution <sup>[2]</sup>. In addition to the normally distributed stochastic error term, the technical inefficiency error, referring to the

inefficiency of the production-cost-profit function, is a part of the estimated composite error, which has a unidirectional distribution structure (discrete normal, exponential, gamma, etc.), <sup>[21]</sup>. Therefore, the composite error term involves the symmetrical stochastic error and unidirectional technical inefficiency term, referring to shifts of enterprises from the benchmark.

After the composite error term is disaggregated and the technical inefficiency is obtained, the methodology enables interpretation of the reasoning of the technical inefficiency. In this, manner, the demographic and socio-economical situation of the farms and farmers are considered as independent variables explaining the retrieved technical inefficiency figure referring to the shifts from the benchmark due to technical incapability of enterprises <sup>[5]</sup>.

The applications of stochastic frontier estimation are similar for agricultural production, despite having a more complex structure. Reducing the level of inefficiency for a farm can also be maintained either by reducing the amount of inputs or by increasing the amount of outputs. The observation units, farms for agricultural production case, are ranked according to the estimated production, cost or profit frontier. Therefore, the inefficiency values are regressed against the demographic, environmental or structural features of the farms in order to determine the factors impacting technical inefficiency and their level of impact <sup>[24]</sup>.

As it is understood for the case, the parametric methodologies, specifically the stochastic frontier approaches, produce inferable outcomes for the technical capacity of the production unit for either agriculture or other productive sectors. As the review of methodological improvements for measurement of the productive efficiency is provided, it is beneficial to review recent applications of different methodologies and the outcomes obtained in agriculture is essential.

**Recent Studies:** There are various studies concerning technical efficiency analysis in agriculture, with a given complex input structure ranging from land, water to labour and chemical ingredients. Some recent analyses mainly incorporating stochastic frontier approach, which provides more inferable outcomes are as following.

In a study focusing on efficiency of agriculture of developing countries, 30 cases from 14 different countries were interpreted through technical efficiency indices. As a result of the study, it was found out that it was possible to retain more output regardless of excess input utilisation under the given technological constraint <sup>[11]</sup>.

Two different stochastic frontier functions were estimated in China in order to interpret productive efficiency of conventional and hybrid rice. Conventional production was found more technically effective and it was understood that education and farm land (acreage) is positively correlated with the technical efficiency of hybrid rice production <sup>[29]</sup>.

In a study undertaken in Northern Ghana among 256 rice producers to estimate profit efficiency of enterprises, the inefficiency index based upon deduction of half-normally distributed stochastic error term was found to be related with enterprise and household characteristics. It was also understood that ageing of the farmer and involvement of the farmer in non-farm activities reduce technical efficiency. Besides, it was found that farms receiving extension services and integrated to input distribution channels produce more efficient outcomes in terms of technical efficiency <sup>[1]</sup>.

The productive efficiency of conventional and organic olive cultivating farms in Greece was estimated through input based production function. The technical inefficiency component estimated was found to be related with family labour share in the total labour cost, size of the farm, capital stock and regional differences. It was found that the level of technical efficiency in organic enterprises is 69.13 %, while it is 58.73 % for conventional enterprises. Besides, it was also found that the variation of the efficiency among enterprises is higher for organic enterprises <sup>[28]</sup>.

In a study based on profit function approach for interpretation of agricultural inefficiency in Russia, cost functions are used in order to set forth relationships between technical inefficiency and distance functions, relationship between input demand and output supply and to demonstrate technical inefficiency scores constituting the profit function. The system also applied to combine allocation efficiency scores <sup>[2]</sup>.

It was understood from a production frontier study undertaken in Ghana among onion, green pepper and tomato producers that there is a considerable variation of the efficiency for all products. Technical efficiency in green pepper was found to be related with farmer's level of education, the distance of farm to the market and extension services. The age of the farmer, his level of education, distance of the farm to farmer's house and methods applied to increase productivity of the land were found to be effective in terms of tomato efficiency. Yet, efficiency in onion production was influenced by farming experience, distance to market and extension services <sup>[7]</sup>.

Stochastic production frontier estimation was conducted among 252 dairy farms in New South Wales district of Victoria – Australia. The level of efficiency for the observed farms was found out to be 87 % and there found a variation of yield across regions. The main determinant of technical efficiency was milk yield per cow according to the findings <sup>[20]</sup>.

In a technical efficiency analysis of tomato and asparagus production in Navarra, Spain, production function was estimated with parametrical and non-parametrical methods. The results indicated that both products were produced out of limits of technical

efficiency. The technical efficiency indices were found to be positively related with partial productivity indices and negatively with cultivation costs per hectare <sup>[16]</sup>.

In a stochastic profit frontier estimation conducted for Bangladeshi rice producers with reference to 1996 data, the average technical efficiency was found out to be 77 %, indicating a 23 % profit loss due to technical inefficiencies. The variation of technical efficiency was correlated with agricultural infrastructure, yield per acre, experience and extension services <sup>[26]</sup>.

In 19,000 large scale farms in Russia, the relationship between the translog production function and debt and subsidies was surveyed and the production values and subsidies were found to be inversely related to each other <sup>[6]</sup>.

A stochastic profit frontier analysis was conducted in 50 rice farms per each of the four agriculturally oriented regions of Nigeria. The stochastic frontier estimation produced more sound outcomes compared to the OLS estimation, in which the random inefficiency impact is neglected. The average profit efficiency of rice farms was found out to be 60.1 %. Besides, the reasoning of the profit efficiency was attributed to both technical and allocation of resources inefficiencies <sup>[19]</sup>.

There are also quite a number of efficiency studies conducted for measurement purposes in Turkish agriculture in recent years. Besides, there are also methodological surveys devoted to determination of the proper efficiency measurement analysis <sup>[12]</sup>. Some of the recent efficiency studies are as following.

A translog stochastic production function was formed for 1993-1995 production data of 67 provinces in Turkey. In this study, agro-climate and environmental factors such as amount of precipitation and quality of production area were used in estimation of the production function in accordance with a regional comparison across sampled units due to inefficiency figures <sup>[14]</sup>.

In a fishery economics study undertaken in Black Sea Region of Turkey, Data Envelopment Analysis was used in order to determine cost efficiency of the trout farms. The tobit analysis applied to 71 trout farms in the scope of stratified sampling revealed a concrete relationship between technical inefficiency and lack of technical knowledge and cost inefficiency <sup>[13]</sup>.

In a profit inefficiency analysis of vegetable producers of Samsun province between 2002 and 2003, the reasons of inefficiency were analysed. It was understood at the end of the frontier estimation of Cobb Douglas production function through data retrieved from 75 producers that the vegetable producers could produce 18 % more with their existing resources and technology. In this study, education, experience, credit use opportunities, women participation to farm activities and level of knowledge were found as determinants of technical inefficiency <sup>[9]</sup>.

**Conclusions:** Effective production by using appropriate input-output structure is something more than receiving accounting profits. The process of transformation of inputs to outputs has crucial importance in interpretation of success of a production system. The success of the process can be explained through productive or economic efficiency, which means production of maximum amount/value of outputs with utilisation of minimum amount/value of inputs under a given technological constraint. Therefore, productive efficiency refers to best technical practices and best possible resource allocation incorporated in the production system, in other words the sum of technical and resource allocation efficiencies.

There are various methodologies developed to measure technical efficiency, the technical capability of an input transformation system. Within this paper it is aimed to review the different measurement approaches of technical efficiency and their use in agriculture. There are three main methodologies developed to measure technical efficiency. First one is non-parametric method exemplified in Data Envelopment Analysis. This sort of analyses depends on classification of quantitative and qualitative facets of production, which provides the researcher with interpretation of a single input and its distance to the ideal input set. The second method applied is partial productivity indices. These indices indicate the ratio of inputs to the output. Yet, the procedure is not completely appropriate for inference of impacts of multiple input cases such as agricultural production due to hardship of disaggregating the source of variation. The third methodology is parametric approach depending upon estimation of proper production, cost or profit functions. The functions can either be estimated either deterministically or a stochastically. In deterministic estimation, all variation from the average sector or sample mean or the frontier, are attributed to technical inefficiency. However, the variation can be disaggregated in terms of technical inefficiency and stochastic influence of out-of-production factors in the stochastic frontier estimations. Accordingly, as the technical inefficiency term is filtered, it becomes possible to investigate the reasoning of the inefficiency or the distance to the frontier.

Accordingly, the stochastic frontier estimations are the most appropriate tools to question technical incapability of production units, farms and other agricultural holdings. Following the methodological review, some examples of applications of technical efficiency analyses on agricultural are provided within the paper. The methodologies, specifically the stochastic frontier approach reveals strong relationships between inefficiency of the agricultural production and farmer / farm characteristics, environmental influences and socio-economic factors impacting on the input transformation process.

## ACKNOWLEDGEMENT

This paper was supported by the Scientific Research Projects Administration Unit of Akdeniz University.

## REFERENCES

1. Abdulai, A., W.E. Huffman, 1998. An Examination of Profit Efficiency of Rice Farmers in Northern Ghana, Staff Paper, Swiss Federal Institute of Technology, Department of Agricultural Economics, pp: 27.
2. Arnade, C., M.A. Trueblood, 2002. Estimating a Profit Function in the Presence of Inefficiency: An Application to Russian Agriculture, *Journal of Agriculture and Resource Economics*, 27, pp: 94–113.
3. Apezteguia, B.I., M.R. Garate, 1997. Technical Efficiency in Spanish Agro-food Industry, *Journal of Agricultural Economics*, 17, pp: 179–89.
4. Bagi, F.S., 1982. The Relationship between Farm Size and Technical Efficiency in Western Tennessee Agriculture, *Southern Journal of Agricultural Economics*, pp: 139-44.
5. Bailey, D.V., B. Biswas, S.C. Kumbhakar and K. Schulties, 1989. An Analysis of Technical, Allocative and Scale Inefficiency: The Case of Ecuadorian Dairy Farms, *Western Journal of Agricultural Economics*, 14(1): 30-37.
6. Bezlepkina, I.V., A. Lansink, 2006. Impact of Debts and Subsidies on Agricultural Production: Farm-Data Evidence, *Quarterly Journal of Agriculture*, 45(1): 7–34.
7. Bhasin, V.K., 2002. Agricultural Productivity, Efficiency and Soil Fertility Management Practices of Vegetable Growers in the Upper East Region of Ghana, Sadaoc Foundation Research Publication, Ghana.
8. Black, J., 1997. *Oxford Dictionary of Economics*, Oxford University Press, New York.
9. Bozoglu, M., V. Ceyhan, 2006. Measuring Technical Efficiency and Exploring the Inefficiency Determinants of Vegetable Farms in Samsun Province, Turkey, *Journal of Agricultural Systems*, 94: 649–56.
10. Brada, J.C., A.E. King, 1993. Is Private Farming More Efficient Than Socialised Agriculture? *Economica*, 60-237, pp: 41–56.
11. Bravo-Ureta, B, L., Rieger, 1991. Dairy Farm Efficiency Measurement Using Stochastic Frontiers and Neoclassic Duality, *American Journal of Agricultural Economics*, 73: 421-28.

12. Candemir, M., E. Deliktaş, 2002. Technical Efficiency, Scale Efficiency, Technical Progress, Changes in Efficiency and Productivity Analysis in TIGEM Enterprises, 1999–2003: 141.
13. Cinemre, H.A, V. Ceyhan, M. Bozoğlu, K. Demirkılıç and O. Kılıç, 2006. The Cost Efficiency of Trout Farms in the Black Sea Region, Turkey, *Journal of Aquaculture*, 251: 324–32.
14. Demir, N., S.F. Mahmud, 2002. Agro-climatic Conditions and Technical Inefficiencies in Agriculture, *Canadian Journal of Agricultural Economics*, 50: 269–80.
15. Gilligan, D.O., 1998. Farm Size, Productivity and Economic Efficiency: Accounting Differences in Efficiency of Farms by Size in Honduras, Paper presented in 1998 American Agricultural Economics Association Annual Meeting, Salt Lake City, Utah, U.S.A.
16. Iráizoz, B., M. Rapún and I. Zabaleta, 2003. Assessing the Technical Efficiency in Horticultural Production in Navarra, Spain, *Journal of Agricultural Systems*, 78: 387–403.
17. Jeffrey, S.R., H.A.R. Grant, 2002. An Economic Analysis of Productive Efficiency in Alberta Dairy Production, University of Alberta, Project Report, AARI Project, 97M090.
18. Jeffrey, S., 1992. Relative Technical and Allocative Efficiency for Canadian and US Dairy Farms, University of Manitoba, Department of Agricultural Economics and Farm Management, 92-4.
19. Kolawole, O., 2006. Determinants of Profit Efficiency Among Small-Scale Rice Farms in Nigeria, Paper presented in Agricultural Economists Conference, Gold Coast, Australia.
20. Kompas, T., T.N. Che, 2003. Australian Bureau of Agriculture and Resource Economics.
21. Kopp, R.J., 1981. The Measurement of Productive Efficiency: A Reconsideration, *The Quarterly Journal of Economics*, 96(3): 477–503.
22. Kumbhakar, S.C., G.E. Tsionas, 2006. Estimation of Stochastic Production Functions with Input-Oriented Technical Efficiency, *Journal of Econometrics*, 133: 71-46.
23. Lengemeier, M.R., F.D. De Lano, 1999. Characteristics of Highly Efficient Farms, Paper presented in Western Agricultural Economics Association Annual Meeting.
24. Ogunyinka, E.O., I.A. Ajibefun, 2004. Determinants of Technical Inefficiency in Farm Production: Tobit Analysis Approach to the NDE Farmers in Ondo State, Nigeria, *International Journal of Agriculture and Biology*, Pakistan, 6-2: 355–58.
25. Oyeranti, O.A., 2000. Concept and Measurement of Productivity in Productivity and Capacity Building in Nigeria, *Proceedings of the Ninth Annual Conference of the Zonal Research Units of the Central Bank of Nigeria*, 12th-16th June, Abeokuta, pp: 16-35.
26. Rahman, S., 2003. Profit Efficiency among Bangladeshi Rice Farmers, Paper presented in 25<sup>th</sup> Conference of International Agricultural, Durban, South Africa.
27. Richards, S., T. Jeffrey, 1996. Cost Efficiency in Alberta Dairy Production, University of Alberta, Department of Rural Economy, Staff, 96-13.
28. Tzouvelekas, Pantzios, C.J., C. Fotopoulos, 2001. Technical Efficiency of Alternative Farming Systems: The Case of Greek Organic and Conventional Olive-Growing Farms, *Journal of Food Policy*, 26: 549–69.
29. Xu, X., S.R. Jeffrey, 1995. Efficiency and Technical Progress in Traditional and Modern Agriculture: Evidence from Rice Production in China, University of Alberta, Department of Rural Economy, Staff Paper.