Journal of Science and Sustainable Development (JSSD), 2015, 3(1), 39-58

ISSN: 2304-2702 (print); 2414-4479 (online)
DOI: https://doi.org/10.20372/au.jssd.3.1.2015.038

Technical Efficiency of Milk Production: Concept and Global Scenario

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Abstract

This review presents the concept, importance, global scenario and determinants of technical efficiency of milk production. Technical efficiency of milk production is basically a measure of how well the individual dairy farmer transforms inputs into output/milk based on a given set of technological and economic factors. Technical efficiency of milk production can also be defined as the ability of a dairy farmer to produce maximum output under given set of inputs and technologies. It is also expressed as the ratio of a farmer's observed output to the technically maximum possible output/ production frontier at the given level of resources. Measurement of farm level efficiency of milk production is useful in providing insights into the competitiveness of the farms, potential for raising their productivity and improving resource uses. Improving technical efficiency is important to reap the potential benefits of the existing technology rather than searching for new technology. Embarking on new technologies alone is meaningless unless technical efficiency using the existing technology is achieved to its full potential. Improvement in technical efficiency which in turn maximizes milk production is the key to meet the growing demand for milk and milk products in the years to come. Increasing the efficiency in milk production is an important factor of productivity growth and this can be achieved by using better technologies along with better management of inputs, which are at the disposal of the farmers. Technical efficiency measures for dairy farms have been reported for many countries in a wide range of studies however, efficiency analyses reports in Africa in general and in Ethiopian dairy farms in particular are scanty. Technical efficiency of farmers is mainly affected by the socio-economic and demographic factors. Variables like size of the farm, age, training, extension services and education level of the farmers appeared significant in explaining differences in technical efficiency across the dairy farms. Therefore, studying farm efficiency and the potential sources of inefficiency are important from a practical and a policy point of view as farmers could use this information to improve their performance and the policy makers could use this knowledge to identify and target public interventions to improve farm productivity and farm income and thereby improve the general livelihood of the dairy farmers.

Key words: Technical efficiency, milk production, technical inefficiency, determinants of efficiency

Introduction

In most of the developing countries, the number of milk animals per household is decreasing from time to time due to the decreasing trend of land to man ratio. The decreasing population of milk animals certainly needs taking up dairying on modern lines and increasing the milk production efficiency of the dairy cows to feed the growing population as well as to supplement the income of the dairy farmers, particularly for the rural poor. Growth in milk production cannot be achieved by technological progress alone but, the interplay of technological advancement and strategic use of inputs. A number of studies (Ortega *et al*., 2002; Zibaei *et al*., 2008; Reddy *et al*., 2008) have examined the potential of the dairy sector to meet the expected growth in demand as well as to improve the income of the farmers. Some of these studies, however, have focused more on technological and non-technological constraints of the sector including poor genotype of local breeds, animal diseases, availability of feed, input and output markets and related policies ignoring an important source of growth i.e. improving the technical efficiency of the dairy farmers (Nega and Simeon, 2006).

Increasing the efficiency and competitiveness of dairy farming is one of the key management practices in the context of dairy development. To make dairy industry efficient, concrete understanding of the performance of the various dairy farms is very important as it helps policy makers to better select among the alternative strategies which can reduce efficiency gap between different dairy farms (Yoon and Park, 1988). In light of the general objective of attaining self-sufficiency in livestock products, governments and institutions have sought strategies that would lead to higher levels of milk production. Change in technical efficiency is a key factor towards a sustained increase in livestock production and productivity (Nkamleu, 2004). Many developing countries are facing challenges as far as the inadequacy of the livestock products is concerned. To this effect, it is imperative to quantitatively measure the current level of and determinants of milk production efficiency for further enhancement of the present level of efficiency.

Most of the dairy farmers in developing countries are still using traditional management practices which lead to low productivity and production of livestock. The important question for policy makers is therefore, whether the livestock sector can be made more efficient, by achieving more output with the current input level, or by achieving the current output with less input than currently used. Therefore, estimation of output based measure of technical efficiency and the quantum of excess or sub-optimal use of different inputs compared to those of the frontier values would help the milk producers to allocate their scarce resources optimally and judiciously to increase milk production.

Concepts of technical efficiency

Technical efficiency is the ratio of a farmer's observed output to the technically maximum possible output/ production frontier at the given level of resources (Ortega *et al*., 2002). The ratio between the actual and the potential out puts given the quantities of inputs used is defined as a measure of technical efficiency of an economic decision making unit. Technical efficiency is the ability of a farm/ farmer to achieve maximum possible output with available resources. Thus, it is an indicator of productivity of the farm and the variation in technical efficiency can reflect the productivity differences among the farms. Technical efficiency can also be considered in terms of the optimal combination of inputs to achieve a given level of output (an input-orientation), or the optimal output that could be produced at a given set of inputs (an output-orientation) (Herrero and Pascoe, 2002). Technical efficiency of milk production is basically a measure of how well the individual dairy farmer transforms inputs into output/milk based on a given set of technology and economic factors (Ortega *et al*., 2002). It has also been defined as the ability of a dairy farmer to produce maximum output under given set of inputs and technologies (Zibaei *et al*., 2008). In order to be economically efficient, a farm must first be technically efficient because technical efficiency is a component of overall economic efficiency. According to Singh and Sharma (2011), technical inefficiency of milk production is the "inability of the farm to produce maximum possible milk production with a given bundle of inputs" A farm that is inefficient is wasting inputs because it does not produce the maximum attainable output, given the quantity of inputs used (Abdulai and Tietje, 2007).

The concept of technical efficiency is illustrated in Figure 1. Perusal of the figure reveals that if everything works perfectly, the particular set of inputs yields an output at point "a" on what is usually called the production frontier (maximum level of technical efficiency). In this regard, individuals using the same set of inputs, but with values below the production frontier are considered less technically efficient. This leads to seek answers to what extent do the production units lie below the frontier and what factors influence production units lying below the frontier.

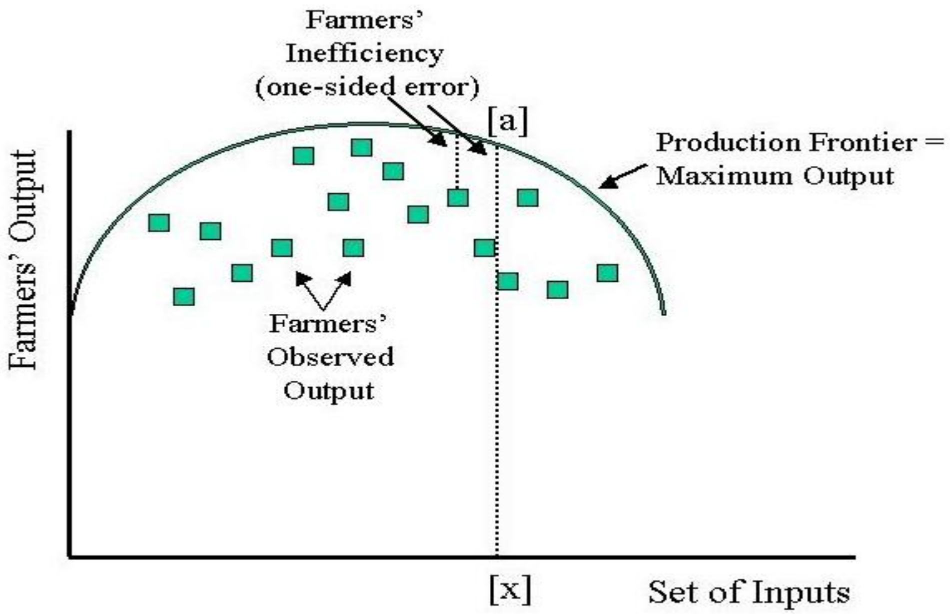

Figure 1. Frontier production function

Farell (1957), who was a pioneer in the work of economic efficiency, disaggregated economic efficiency into two viz., technical efficiency (TE) and price or allocative efficiency (AE). On the other hand technical inefficiency refers to failure to operate on the production frontier which in turn is the highest possible production achieved from a given level of available inputs in a population of farmers or it can be defined by reference to a potential frontier based on experimental data. Allocative inefficiency generally refers to failure to meet the marginal condition for profit maximisation. Profit maximization requires a farm to produce the maximum output given the level of inputs employed (i.e. be technically efficient), use the right mix of inputs in light of the relative price of each input i.e. be input allocative efficient and produce the right mix of outputs given the set of prices i.e. be output allocative efficient (Herrero and Pascoe, 2002). Economic efficiency is a function of measured technical efficiency and allocative efficiency. More recent work in production economics (Herrero and Pascoe, 2002; Coelli *et al.*, 2003; Nkamleu, 2004) seeks to define the 'best practice' frontier production function and to measure the distance individual farms are from this frontier. This distance is interpreted as a measure of the level of technical inefficiency of that farm. In addition to increases in conventional inputs which cause movements along the frontier production function and increases in non-conventional inputs which cause a shift in the frontier production function, changes in output can also be due to changes in technical efficiency i.e. the distance that individual farms are from the frontier (Suzanne *et al*., 2000). The measure of technical efficiency of a farm indicates that if any farm is successful in converting all the physical inputs into output and the efficiency of converting is equal to the frontier production, then it is said to be an efficient farm and if any farm falls short of this requirement, then it is technically inefficient (Reddy *et al*., 2008). This discrepancy could be due to inadequate technical knowledge of the latter. Therefore, knowledge of farm efficiency and the potential sources of inefficiency are important from a practical and a policy point of view as farmers could use this information to improve their performance and the policy makers could use this knowledge to identify and target public interventions to improve farm productivity and income.

Estimation of technical efficiency

The two most popular approaches to estimate technical efficiency are the parametric stochastic frontier analysis (SFA) and non-parametric data envelopment analysis (DEA). Each of the two approaches has its strengths and weaknesses. While the advantage with DEA lies in its general non-parametric frontier, its limitations are related to the fact that it attributes all deviations from the frontier to inefficiency ignoring stochastic noises in the data. On the other hand the strength of SFA lies in its ability to segregate the error term into two components, viz. inefficiency and statistical noise, but it can be implemented only by imposing a specific functional form and hence the efficiency indicators obtained can be sensitive to a chosen functional form (Gelan *et al*. 2010). Literature on efficiency analysis has taken two major paths as parametric and non-parametric depending on whether the functional form of the frontier is pre-defined (parametric) or estimated from the sample observations empirically non-parametric (Edirisinghe *et al.,* 2007). The parametric analysis is further subdivided into deterministic and stochastic frontiers. In the deterministic framework, the frontier is defined such that it envelopes all the observations and any deviations from the frontier is assumed to be due to inefficiency. This implies that the deviation is assumed to be under the farmers' control. However, this may not be a valid assumption as there may be situations such as weather, socio-economic factors, uncertainty, etc. which are beyond the control of the farmer. Stochastic frontier analysis will be employed where the deviation from the frontier is assumed to have 'noise' effect and inefficiency effect. Technical efficiency of milk production of the dairy farmers/farms is mostly evaluated using a Stochastic Frontier Analysis (SFA) of the Cobb-Douglas production model which was initiated by Aigner *et al*. (1977) and

Meeusen and Broeck (1977). This technique allows the construction of technical efficiency frontiers, which are used as reference points for comparisons among the analyzed units, i.e. once the frontier is built the efficiency of each farm can be measured in relation to it. Any deviation of a farm from the frontier indicates the extent of farm's inability to produce maximum output from its given sets of inputs and hence represent the degree of technical inefficiency. The stochastic frontier production model is expressed as:

$$Y = (X_{ij};\beta) + \varepsilon$$ where,

Y = the output of the j^{th} farm,

X ij = the i^{th} input used by the j^{th} farm

β = a vector of unknown parameters and

ε = a composed error term which can be written as: $\varepsilon = v - u$ *where,* **v** is a symmetric random error which represents random variations outside the control of the farmer assumed independently and identically distributed as $N(0, \sigma^2)$. The error term **u** is one-sided that measures technical inefficiency, the extent to which observed output falls short of the potential for a given input levels and technology (technical inefficiency effects which cause the farm to operate below the stochastic production frontier). The distance of the actual production point below the production frontier (implied by maximum production) is considered as a measure of technical inefficiency of the given farm. If $u_i = 0$, production lies on the stochastic frontier and production is technically efficient if, u_i is > 0, production lies below the frontier and is inefficient. Given the density function of u_i and v_i, the frontier production function can be estimated by maximum likelihood techniques.

The output oriented technical efficiency of the i^{th} farm denoted by TE_i can be estimated as the ratio of the observed output (yi) and maximum potential output (y *):

$$TE_i = \frac{y_i}{y^*} = \frac{f(x_{ij};\beta).exp(v_i - u_i)}{f(x_{ij};\beta).exp(v_i)} = exp(-u_i)$$

$$TI_i = 1 - TE_i$$

where; *i, j* = denote the farm and input , respectively

TE_i = Technical efficiency of the i^{th} farm

TI_i = Technical inefficiency of the i^{th} farm

$exp(-u_i)$ = Expected value of $-u_i$

The model is estimated by using stochastic production function and the Maximum Likelihood Estimates (MLE). If a Cobb-Douglas form is used, the coefficients directly estimate the elasticity with respect to each input.

Following Battese and Corra (1977), the parameters of the model can be obtained considering the parameter gamma $(\gamma) = \sigma^2 u / \sigma^2 v + \sigma^2 u$ which is bounded by 0 and 1, and $\sigma^2 = \sigma^2 v + \sigma^2 u$ is the variance of the composite error term vi – ui. If $\sigma^2 v = 0$, γ would be equal to 1 and all the differences in error terms of the frontier production function are the results of management factors under the control of the producer and in the case of $\sigma^2 u = 0$, γ would be equal to 0 which means all the differences in the error terms of the frontier production function are the results of factors that the producer has no control on them. The magnitude of the **ui** value varies among farms depending on the factors under the farm's control. The variance ratio, gamma specifies the ratio of variation due to inefficiency to the total variations. A higher value of gamma is an indication of the presence of inefficiency. The model is estimated using the computer programme FRONTIER 4.1 (Coelli, 1996) to estimate simultaneously the parameters of the stochastic production frontier and the technical inefficiency effects. The computer program calculates predictions of individual farm technical efficiencies from estimated stochastic production frontiers.

Why technical efficiency analysis?

Technical efficiency analysis of farmers is important because the majority of smallholder farmers are resource poor. Due to this reason, it is prudent to inquire into the ways and means of using the existing resources to the maximum rather than advocating high investment for the smallholder farmer. Technical efficiency analysis enables to analyze the impact of exogenous influences by characterizing the environment in which production takes place, and on producer performances which is paramount in policy decisions (Edirisinghe *et al*., 2007). Measurement of farm level efficiency of milk production is useful in providing insights into the competitiveness of the farms, potential for raising their productivity and improving resource uses (Rajendran and Samarendu, 2005). The measurement of technical efficiency is important because it helps in both policy formulation and farm management. Producers benefit directly from improvements in their technical performance because more efficient farms tend to generate higher incomes and thus have a better chance of surviving and staying in business (Victor and Boris, 2009). Improving technical efficiency is also important to reap the potential benefits of the existing technology rather than searching for the newer ones.

The production environment in which a farm operates determines the variation in the efficiency level of the farm household (Bhende and Kalirajan, 2007). Milk producers in general have a tendency to use resources as efficiently as possible even though certain inefficiencies exist, particularly with the producers who lack knowledge but have rich natural resources and use the inputs in excess expecting to reap higher yield (Shiyani, 1993).

Embarking on new technologies is meaningless unless technical efficiency using the existing technology is achieved to its full potential. Further, the analysis of variation between the potential and actual yields on the farm, given the technology and resource endowment of farmers, provide better

understanding of the yield gap. In this context technical efficiency in milk production assumes paramount importance. In other words, improvement in technical efficiency is the key to meet the growing demand for milk and milk products in the years to come. Increasing the efficiency in milk production is a very important factor of productivity growth and can be achieved by using better technologies along with better management of inputs, which are at the disposal of the farmers. Under these circumstances, reducing inefficiency (increasing efficiency) is the best way to enhance productivity.
In an environment of growing liberalization, productivity growth, which is a major element of competitiveness, is essential to insure the prosperity of agriculture in general and dairy farming in particular (Victor and Boris, 2009). However, the heterogeneity in dairy husbandry practices employed by the dairy farmers may explain the differences in technical efficiency. For all agricultural sectors, achieving a high level of technical efficiency is essential for competitiveness and profitability and has also direct implications for the public welfare since resources are used more effectively (Ortega *et al*., 2002).

Technical efficiency of milk production: Global scenario

Aigner *et al.* (1977) brought out full-fledged stochastic frontier production function estimation while studying technical efficiency. They assumed a truncated normal distribution for the technical efficiency component along with a normal distribution for the random disturbance term. Battese and Corra (1977) were the first to apply stochastic frontier production function estimation to farm-level agricultural data. They used Australian grazing industry survey data to estimate deterministic and stochastic Cobb-Douglas production frontier. Shapiro (1983) also estimated technical inefficiency to be as high as 30 per cent in Brazilian agriculture and 34 per cent in Tanzanian agriculture.

Measures of technical efficiency in milk production based on a frontier production function model of the Cobb- Douglas type revealed a mean technical efficiency of 82.17 per cent that ranged between 57.9 and 100 per cent (Boris, 1986). The measurement of farm-specific technical efficiency of milk production in Kyungki region, Korea using a stochastic frontier production approach showed a technical efficiency range from 32 to 95 per cent with a mean of 79.95 per cent (Yoon and Park, 1988). The result of this study suggested that there remains a large room for increasing milk production levels of dairy farms with lower efficiency. In a study conducted to analyze technical efficiency of New England dairy farms using stochastic model, the mean technical efficiency for the farmers was found to be about 83.0 per cent (Boris and Laszlo, 1991). Kumbhakar (1994) used a stochastic production function to estimate the efficiency of 227 farms in West Bengal, India. The mean level of technical efficiency was found to be 75.76 per cent while the best farm had about 85.87 per cent technical efficiency in milk production. Shiyani and Singh (1996) studied an economic analysis of technical efficiency in milk production amongst member and non-member milk producers in villages that supplied milk to four dairy cooperatives of the Junagadh District Cooperative Milk Producers Union, Gujarat, India. The results revealed that the output efficiency of cow milk ranged from 79.08 to 89.72 per cent for member and from 72.55 to 81.98 per cent for non-member milk producers, whilst that of buffalo milk correspondingly ranged from 81.64 to 84.39 per cent for members and from 72.52 to 79.79 per cent for non-members. In the case of member milk producers, about 6 (during summer) to 19 per cent (during winter) of the total milk cows were maintained at an efficiency level of more than 80 per cent, while the corresponding figures for the non-members were nearly 1 to 6 per cent for rainy and winter seasons, respectively. It was concluded that, the output efficiency of milk production was found to be high during winter season as compared to other seasons.

Jeffrey and Richard (2000) had reported an average technical efficiency level of 86.40 per cent in Alberta dairy farms. They also stated that about 10.30 per cent of the sample dairy farms had 100 per cent efficiency in milk production. Qiuyan (2001) reported a mean technical efficiency of 85 per cent in Pennsylvania dairy farms, USA. The result indicated that large farms were technically more efficient than the small ones. Ortega *et al.* (2002) reported that in the dual-purpose cattle system (DPCS) in the lowland tropics of Latin America, 25 per cent of the farms had relatively high level of technical efficiency above 88 per cent while 25 per cent of the farms had technical efficiency levels from 50 to 76 per cent and nearly 50 per cent of the farms were in the 76 to 88 per cent range of technical efficiency.

A technical efficiency range of 65 to 93 per cent was reported for Argentinean dairy farms using a Stochastic Production Frontier (Victor *et al.*, 2002). An input distance function approach to the measurement of technical and allocative efficiency of Indian dairy processing plants revealed a mean technical efficiency of 87.4 and 84.6 per cent for cooperative and private dairy plants, respectively (Coelli *et al*., 2003). In a study conducted to examine the profitability and efficiency of Indian dairy farms of the northern and western regions, the mean technical efficiency was found to be about 81 per cent which implied, on an average, the dairy farmers were producing milk to about 81 per cent of the potential frontier production levels, given the levels of inputs and technology in use (IFPRI, 2003). The average technical efficiency of the farmers in the northern and western regions was estimated to be 79 and 84 per cent, respectively. About 57 per cent of the farmers had technical efficiencies in the range of 80-90 per cent, while about 22 per cent of the farmers had technical efficiency range of 70-80 per cent. A study on production and technical efficiency of Australian dairy farms of two states (New South Wales and Victoria) revealed a mean technical efficiency of 88.34 per cent with a range from 71.18 to 100 per cent in New South Wales, 86.75 per cent with a range from 69.42 to 96.61 per cent in Victoria and higher mean efficiency (87.39 per cent) with a range from 69.42 to 100 per cent for the combined New South Wales and Victoria (Kompas and Che, 2003). Manoharan *et al*. (2004) had reported a mean technical efficiency of 82.28 per cent for local and crossbred cows in the Union Territory of Pondicherry, India. About 18 per cent of their technical abilities were not realized. The authors also observed that the farm specific variability contributed more to the variation in yield among the dairy farmers, indicating that 80 per cent of the differences between observed and the maximum production frontier output were due to difference in farmers' level of technical efficiency.

A mean technical efficiency of milk production of 91.1 per cent ranging from 73 to 98 per cent across the farm households of Haryana state, India was reported by Saha and Jain (2004). Margarita and Lerman (2005) had reported a mean technical efficiency of 73.5 per cent in corporate farms of Russia. Similarly, Rajendran and Samarendu (2005) reported a mean technical efficiency of 52 per cent (ranging from 43 to 55 per cent) in Tamilnadu, India. They suggested that about 48 per cent of the farms were operating below their respective mean level of technical efficiency which warranted reallocation of the available inputs to get maximum output. According to the study, the management practices such as feeding, breeding and health care were found to affect milk yields for all the categories of farmers. Observed feeding practices suggested that farmers were over feeding cheap green fodder and under-feeding more expensive concentrate. In addition, the results suggested that excessive utilization of labour may have a negative impact on the profitability of dairy cows.

Herve *et al.* (2006) had reported an average technical efficiency of 79.1 per cent for French dairy farms. The technical efficiencies of milk production on conventional and organic farms in Austria were studied and reported by Karagiannias *et al.* (2006). The results revealed that, on average conventional farmers were technically more efficient with a mean efficiency of 84.3 per cent as compared to organic farmers with technical efficiency level of 80.9 per cent. A study on multi-output technical efficiency for Argentinean dairy farms using Stochastic Frontier Production revealed a mean technical efficiency of 88.4 per cent (Moreira Lopez *et al.*, 2006). The correlation coefficient for technical efficiency scores in the study ranged from 0.63 to 0.97. Nega and Simeon (2006) had reported a mean technical efficiency of 79 per cent with a range from 44 per cent to 98 per cent for the smallholder dairy farmers in the central highland of Ethiopia. The result implied that on an average, milk production can be increased by 21 per cent with the existing technologies and inputs by training the dairy farmers on improved husbandry practices. According to the study only 23 per cent of the farmers had achieved efficiency level of more than 90 per cent.

The mean efficiency of the Sri Lankan smallholder dairy milk production was found to be 52 per cent (Edirisinghe *et al*., 2007). The result indicated that an efficiency gain of 48 per cent can be achieved if the problem of milk production is properly addressed. According to the study, human capital (age, education and training) and knowledge transfer were found to play a key role in developing efficiency. Further, the analysis revealed the importance of veterinary services in income generation to poor farmers. They concluded that, a policy on development of smallholder dairy farming would essentially incorporate the development of veterinary services and knowledge transfer in the producing areas. A study on milk supply chain and efficiency of smallholder dairy producers of milk district and non-milk district in Pakistan revealed a mean technical efficiency of 73.1 per cent (Abid and Mushtaq, 2008). They suggested that, on an average, dairy farms in the study areas lose about 37 per cent of their output due to being technically inefficient. The study further revealed that farms located in milk district cluster were relatively much closer to the production frontier than farms in non-milk district. Boris *et al*. (2008) reported an average technical efficiency of 87.0, 84.9 and 81.1 per cent, for Argentina, Chile and Uruguay dairy farms, respectively indicating that the dairy farmers of the three countries could increase their milk production by 13.0, 15.1 and 18.9 per cent, respectively, without increasing the use of inputs. Fernando (2008) had measured the technical efficiency of dairy farms in Portuguese using a stochastic frontier production model and reported an average efficiency of 84 per cent. The study revealed that about 71 per cent of the dairy farms in the study area had a close proximity to the production frontier. A mean technical efficiency of 83 per cent for milk-producing farms in Minas Gerais, Brazil was reported by Rosiane *et al.* (2008). Theodoridis and Psychoudakis (2008) reported a mean technical efficiency of 81.21 per cent with a wide range of 51.95 to 94.09 per cent in Greek dairy farms.

A technical efficiency range of 72.0 to 86.7 per cent was reported in Iranian dairy farms (Zibaei *et al.,* 2008). The authors concluded that the dairy farms which used high level of veterinary services were technically more efficient than the others. In other words, the level of efficiency of individual dairy farms in Iran can be improved by enhancing the use of veterinary services. Analysis of the efficiency of milk production of dairy farms in Reunion Island, a French overseas district located in Indian Ocean, revealed an average technical efficiency score of 92.7 per cent for the dairy farms assuming constant returns to scale with 19 out of 34 farms not being efficient (Haese *et al*., 2009). The average potential for improvement in technical efficiency of milk production in South Tripura, India was found to be 25 per cent (Joshi, 2009). The result suggested that increasing herd size will tend to raise the efficiency in milk production. Victor *et al.* (2009) in a study on the effect of traditional practices on the efficiency of dairy farms in Wisconsin reported an average technical efficiency of 88 per cent. An average farm could increase its level of milk production by 12 per cent using the current input quantities and technologies. The results also suggested that dairy farms in Wisconsin can improve their productivity and efficiency if they take advantage of more efficient farm practices.

Production inefficiency is usually analyzed by economic efficiency, which is composed of two components-technical and allocative efficiencies. A study conducted in Kenya using a stochastic profit frontier and inefficiency model provided a direct measure of production efficiency of the smallholder milk producers (Nganga, *et al*., 2010). The result showed that profit efficiencies of the farmers varied widely between 26 and 73 per cent with a mean of 60 per cent, suggesting that an estimated 40 per cent of the profit was lost due to a combination of both technical and allocative inefficiencies in the smallholder dairy milk production. The technical efficiencies of small scale dairy growing farms in Cukurova region of Turkey when estimated with a stochastic frontier model recorded a mean technical efficiency of about 78 per cent ranging from 43 to 98 per cent (Tuna *et al*., 2010). The result suggested that there was significant scope for increasing efficiency under the current technology. The result of the inefficiency analysis also indicated that 96 per cent of the variation in milk production was due to farmers' technical inefficiency that could be improved through training without requiring higher cost. Similarly, technical efficiencies of cooperative member dairy farmers in Cukurova region, Turkey were estimated the same model and a mean efficiency score of the sample farms was found to be about 68 per cent (Tuna and Hilal, 2011) implying that there was plenty of scope to increase production under existing technology without incurring additional costs.

A working paper on dairy farm performance by farm type and location and policy implications in the new millennium of China revealed that the average level of efficiency of backyard dairy farms fell from 0.81 in 2004 to 0.65 in 2008; likewise those for small dairy farms fell from 0.85 to 0.70; for medium dairy farms from 0.66 to 0.55 and for large dairy farms from 0.95 to 0.80 (Hengyun *et al*., 2011). The evidence indicated that falling efficiency is partly due to rapid expansion of China's dairy herd size and that at least part of the inefficiency may tend to correct itself when extreme growth abates. The technical efficiencies of extensive Iranian dairy farms using a non-parametric data envelopment analysis model in which all variables were normalized with the number of cows reported a mean technical efficiency of 79 per cent (Narges, 2011) indicating that there was ample potential for more efficient input utilization in dairy farming. Measurement of technical efficiency in dairy sector of India using a stochastic frontier production function approach revealed a wide range of variations (33 per cent to 96 per cent) in the technical efficiency of the dairy farmers (Singh and Sharma, 2011). The mean technical efficiency in dairying was found to be 69 per cent. It was concluded that milk production can be increased by 31 per cent without increasing the level of inputs, if this inefficiency is reduced to level zero. In other words, dairy farmers can gain considerable higher profits just by increasing the efficiency in their operations. According to Lemma *et al*. (2013), the overall mean technical efficiency of milk production of dairy farmers in Ada'a district of Oromia state, Ethiopia was found to be about 65 percent. The low technical efficiency recorded suggests that farmers in the study area were not using the available resources (green fodder, dry fodder, concentrate feed, labor, etc) efficiently / judiciously as evident from about 35 percent inefficiency level of the farmers. This necessitates reallocation of inputs to increase efficiency and thereby maximize milk production in the area.

Determinants of technical efficiency in milk production

In many studies of technical efficiency, the results were used to estimate the effects of various factors responsible for the inefficiency of the farm. These may be estimated using a two-step process in which the production frontier is first estimated and the technical efficiency of each farm, derived. These are subsequently regressed against a set of variables which are hypothesized to influence the farm's efficiency (FAO, 2000). Technical efficiency of farmers is mainly affected by the socio-economic and demographic factors (Kalirajan and Shand, 1989). Analyses of the relationship between technical efficiency and the socio-economic variables viz., farm size, education, extension, and experience revealed that, despite some statistically significant ($P<0.05$) associations, efficiency levels were not markedly affected by these variables (Boris and Laszlo, 1991). Variables like size of the farm, age, training and education level of the farmers appeared significant in explaining differences in technical efficiency across the dairy farms of Irish (Suzanne *et al*., 2000). Likewise, Ortega *et al*. (2002) reported that differences in farm size, production practices and producers' experience have greatest impact on technical efficiency of milk production. Education (years of formal schooling) and age of the dairy farmers were reported as the determinants of technical inefficiency in northern and western regions of Indian dairy farms (IFPRI, 2003). According to this study, generally young farmers were believed to be more efficient than old farmers. Manoharan *et al.* (2004), pointed out that variables like green fodder, concentrate and health expenditure were positive and statistically significant ($P<0.05$) while dry fodder was negative and insignificant in determining milk production. Concentrate was found to be the dominant factor followed by green fodder in determining the milk production but the effect of labour use was not significant. On the other hand, Saha and Jain (2004) had reported green fodder, concentrate and farm family labour as the most important variables in determining the milk production efficiency of the farm. They also added that elasticities of milk production for dry fodder, hired labor and depreciation were not significant suggesting that these variables did not have significant impact on average or frontier levels of milk production.

Veterinary expenditures and health and hygiene index exerted significant and positive influence ($P<0.05$) on milk production efficiency of crossbred cows in Udham Singh Nagar of Uttaranchal, India whereas labour expenditures mostly had negative impact (Dwaipayan and Srivastava, 2006). Concentrate, forage feeds, expenditures on veterinary services, literacy and livestock training were significant determinants of farmers' efficiency in milk production (Nega and Simeon, 2006). Schooling has been shown to provide substantial externality benefits by increasing milk production and shifting the production frontier outwards. The estimates of the coefficient for the Cobb-Douglas frontier production function suggested that, animal capital, fodder and straw and concentrate were found to be the most important determinants of milk production efficiency in smallholder dairying (Abid and Mushtaq, 2008). Similarly, variables, viz., age, education, stocking density and land had positive coefficients and highly significant ($P<0.01$) effect on milk production efficiency (Reddy *et al*., 2008). Though not significant, experience and training had negative influence on milk production efficiency, which may be due to the inappropriate training and experience and lack of technical knowledge.

Labor productivity had significant effect on milk production at 5% probability level, contributing positively to technical efficiency; independent of the production level (Rosiane *et al.*, 2008). The marginal effect indicated that an increase in labor expenses of one unit was associated with an increase in technical efficiency of the production level for categories less than 50 liters/day, from 50 to 200 liters/day and above 200 liters/day of 0.0452, 0.0417 and 0.0201, respectively. According to the report, the impact of labor productivity on technical efficiency was higher for producers from lower production levels, which reflects the importance of labor for these groups. In analyzing the technical efficiency of milk-producing farms in Minas Gerais, Brazil, the variable 'farmers age' was found to affect the technical efficiency of farms with production scale less than 50 liters/day (Rosiane *et al.*, 2008). Due to the fact that the farms had less access to technology, the accumulation of knowledge and experience over a lifetime brings positive impacts on the technical efficiency at this production level. The study revealed that the level of technical efficiency of these farms was not explained by variables such as rural credit, training, technical visits and education, given the limited or non-existent access to these factors. Participation in a training program and use of rural credit were the only significant factors ($P<0.05$) in explaining the variation in technical efficiency of farms at a production level above 200 liters/day. Veterinary services had positive effect on technical efficiency of the Iranian dairy farms (Zibaei *et al.,* 2008). It was concluded that dairy farms which use high level of veterinary services were technically more efficient than the others. Furthermore, access to more suitable veterinary services was recognized to be a major determinant of technical operation.

A study on determinants of technical efficiency among dairy farms in Wisconsin revealed that farm efficiency was positively related to farm intensification, the level of contribution of family labor in the farm activities, the use of a total mixed ration feeding system and milking frequency (Cabrera *et al*., 2010). It was observed that the variable with the highest effect on production was the number of cows on the farm followed by the total expenditure in crops, feeding and labor. The report further indicated that the level of productivity depends on improvements in technology and efficiency, not on the size of the farm. A study conducted in south district of Central Kenya to analyze the efficiency of dairy farmers using stochastic profit frontier function revealed that farmers with higher level of education, more experience and larger farm size (farm specific variable used to explain inefficiency) had tend to be more efficient while those who were aged tend to be less efficient (Nganga, *et al.*, 2010). The implication of the finding in dairy milk production was that the inefficiency in dairy milk production can be reduced significantly by improving the level of education amongst the farmers. Technical efficiencies of small scale dairy farms in Turkey were estimated with a stochastic frontier model using five inputs (grains and concentrate, green and dry fodder, labour, veterinary costs and other costs) and four inefficiency variables (herd size, cow quality, source of labour and share of milk in gross return (Tuna *et al*., 2010). The result revealed that except labor, all inputs of the production function of the model were found to have positive elasticities. Efficiency levels were all affected in the expected direction by the selected determinants of the inefficiency model, however, only cow quality variable was found to be statistically significant (P<0.05). Measurement of technical efficiency in dairy sector of India using a stochastic frontier production function approach revealed that technical efficiency was influenced negatively by age of the dairy farmers, whereas the same was influenced positively by the innovativeness, education level and high economic status (Singh and Sharma, 2011). The study also highlighted the need to promote young farmers in the dairying along with raising their economic status, besides the socio economic changes in the entire region in particular and towards the nation in general. Further, the study revealed that the innovative farmers had been found to be more efficient as compared to the traditional ones. Hence, there is a need to train the farmers to increase their innovativeness by organizing training programs with more emphasis on highbred animals to enable them to adopt the latest technology in the dairy sector.

Concentrate feed and capital costs were found to have statistically significant (P<0.05) contributions to milk production efficiency in Turkey dairy cooperatives (Tuna and Hilal, 2011). Likewise, farm location, herd size, farming experience, on-farm feed growing, milking by equipment and grazing had also effects on milk production efficiency. However, only positive effect of farming experience and negative effect of grazing were statistically significant (P<0.05). Mass media exposure of the dairy farmers, training on dairy farming, dry fodder and concentrate feeds were the significant determinants of technical efficiency of milk production in Ada'a district of Oromia state, Ethiopia (Lemma *et al.,* 2013). They had also reported that, organizational participation of the farmers, education level, labor and experience of farmers in dairy farming had positive effect on the technical efficiency of milk production in the area.

Conclusion

Technical efficiency of milk production is basically a measure of how well the individual dairy farmer transforms inputs into output/milk based on a given set of technology and economic factors. The available evidences had shown that, inputs use as well as output levels/milk production vary across regions and also within the region among different farm sizes. This difference in inputs use and milk production is mainly attributed to difference in the technical efficiency of the farmers.

Improving milk supply from animals through higher livestock numbers as in the past is now severely constrained due to feed scarcity as a result of declining grazing land. The best options to increase livestock productivity are through the adoption of improved technologies and efficient use of available resources. One of the important measures of overall resource use efficiency is technical efficiency. Therefore, it is more lucrative to increase milk production and income by improving the technical efficiency of farmers.
Technical efficiency of farmers is mainly affected by the socio-economic and demographic factors. Variables like size of the farm, age, training, extension services and education level of the farmers appeared significant in explaining differences in technical efficiency across the dairy farms. Therefore, increasing farm size, provisions of need based training and extension services and improving the education level of dairy farmers could enhance their technical efficiency and thereby increase milk production and productivity which eventually results in improved profitability of the dairy farm.

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