The concept of technical and allocative efficiency

Technical Efficiency- Basic Concept

The term “ Technical Efficiency” was first used by M. J. Farrell in 1957 in his seminal paper and differentiated and disaggregated economic efficiency into two components i. e. ‘ technical efficiency’ and ‘ allocative efficiency’. Coelli et al. (1999) define technical efficiency as the maximum achievable output from a given set of inputs and existing technology (Coelli, Rao, & Battese, 1999). It has been also defined as the ratio of actual output and potential output of a farm unit i. e.

In this sense TE refers to the manner in which the inputs or production resources are used. By this definition it is more closely associated with the techniques of framing or understanding of technology and deals with the behavior of how to produce an optimal level of production regardless of input-output price ratio. Hence, technical efficiency is also equivalent to “ Agronomic Efficiency”.

The concept of technical and allocative efficiency can be explained by the help of Figure 2. 1 illustrated by Kalirajan and Shand (1999).

Theoretically, we assume that all units of production (firm or land) operate at potential frontier production function i. e. the points along the curve FF’. Any level of inefficiency with respect to this production function will be purely allocative. The reason may be that the producer has no income to buy inputs or is not willing to spend more for the marginal amount of inputs. Now suppose if the firm operates at point B by using I1 inputs and getting Y1 output. At this point the firm is both technically and allocatively efficient with a maximum profit of Ï€1. When the firm operates at Point-A with I2 level of inputs producing Y2 output points, earning Ï€2 amount of profit. At this point the firm is technically efficient as it is operating at FF’ but it is inefficient allocatively. It can improve its profit by Ï€2/Ï€1 amount. But on real grounds, the units of production operate at less than the level of its potential frontier. The reasons are different technical, socio-economic, bio-physical, organizational and other unknown factors (Ahmed et al., 2002; Ajibefun, 2008; Ozkan et al. (2009)). Thus the firm operates at its actual production function AA’ below the potential frontier FF’. Let us suppose it operates at point C with I2 amount of inputs and producing Y3 yield and earning Ï€3 profits. At this point the firm is neither technically nor allocatively efficient. It could maximize its profit to Ï€4 levels by operating at point D utilizing I3 inputs and producing Y4 outputs.

But on real grounds, the units of production operate at less than the level of its potential frontier. The reasons are different technical, socio-economic, bio-physical, organizational and other unknown factors (Ahmed et al., 2002; Ajibefun, 2008; Ozkan et al. 2009). Thus the firm operates at its actual production function AA’ below the potential frontier FF’. Let us suppose it operates at point C with I2 amount of inputs and producing Y3 yield and earning Ï€3 profits. At this point the firm is neither technically nor allocatively efficient. It could maximize its profit to Ï€4 levels by operating at point D utilizing I3 inputs and producing Y4 outputs.

Thus it is quite clear from Figure 2. 1 that economic inefficiency is composed of two components of technical and allocative inefficiency. The total loss of the firm in profit terms operating at point C is Ï€1-Ï€3. Within this loss, Ï€3-

Ï€2 and Ï€1-Ï€2 are the technical and allocative inefficiency losses respectively.

The efficiency scenarios in these models explain three reasons of farmer’s attributes as discussed by Ellis (1988);

Farmer’s desire to maximize profit with less input levels given by yield gap (Y0 – Y3). Such behavior is referred as “ profit maximization behavior”.

Second reason may be the lack of correct allocation of inputs given by (Y3′ – Y2), and

Farmer’s failure of operating in the most efficient production function (Y3′ – Y3). This gap represents technical inefficiency level, and

Farmer’s behavior to reduce his risk instead of maximizing profit.

-
-
-

Technical Efficiency- History / Evolution

Farrell (1957) is known as the pioneer of efficiency literature when the frontier production model developed by him, in one of his seminal papers, decomposed economic efficiency into two components; i. e. technical and allocative efficiency. He defined TE as the ability of a firm to produce maximum output given a set of inputs under existing technology. Stated differently, technical inefficiency is the failure of attaining the maximum possible level of production given existing resources and technology (Bravo-

Ureta & Pinheiro, 1993). The adoption of new technologies after green revolution for enhancing farm output has acknowledged special attention as a means to accelerate agriculture development after Schultz's hypothesis that " conventional agriculture was fully efficient" (Schultz, 1964). The growth performance is not only determined by such technological innovations but also by the efficient management and utilization of such technologies. The importance of efficiency measures as a means of nurturing productivity a considerable amount of literature is found focusing on agriculture (Bravo-Ureta & Pinheiro, 1993).

The efficiency analysis of units of agriculture inputs (land, labour, fertilizer etc.) has always been the focus of a number of studies since early 1960s. Most of the studies have supported Schultz's " efficient but poor hypothesis". Theodore Shultz stated this hypothesis in 1964 that

" The traditional agriculture is fully efficient in the allocation of inputs under an existing technology. The combination of crops being grown, the depth and number of cultivation, time of planting, fertilizing, watering and harvesting, the combination of tools, draft animals and equipment are all made with a fine regard for marginal costs."

(Schultz, 1964)

Sahota (1968) based on his and many others have supported Schultz's hypothesis in their empirical works. Based on his study in Indian agriculture, Sahota (1968) concludes that the bulk of the evidences appear to support the hypothesis that the resources available to conventional Indian farmers have been, by and large, efficiently allocated (Sahota, 1968).

A large number of frontier models were developed based on Farrell’s work which was than classified into parametric and non-parametric types. Aigner & Chu (1968) were the initiators of “ deterministic parametric approach”. They estimated a deterministic production frontier of a Cobb-Douglas type through linear and quadratic programming techniques. Timmer (1971) further developed this procedure by introducing a “ probabilistic production frontier” model. He estimated a series of production frontiers by dropping extreme observations at each stage until the rate of change of parameter estimates stabilizes. These estimators had undefined statistical properties.

Another class of frontier models was proposed by Afriat in 1972 known as “ statistical production frontiers”. According to Afriat’s (1972) model, technical efficiency is a one-sided disturbance term with some explicit assumptions and frontier is estimated by method of “ maximum likelihood estimation” (MLE). On the other hand if the disturbances are based on no a-priori assumptions, then corrected least squares (COLS) method is used to estimate the production frontier by just shifting the frontier upwards covering all negative disturbance terms.

In 1977, Aigner et al. (Aigner, Lovell, & Schmidt, 1977), and Meeusen and Broeck (1977) independently developed “ stochastic frontier production model” in which the error term was decomposed into two components. A one-sided positive component reflecting inefficiency and a two-sided error component covering measurement errors and the random effects, which are not in control of the producer. Under this model the frontier could be could be estimated either by COLS or MLE. But in 1980, Greene found that the MLE are more efficient than COLS as the former method makes use of special statistical distributions for the disturbance terms e. g. exponential, half-normal or gamma distribution (Greene, 1980).

Another mathematical programming method was developed by Charnes, Cooper and Rhodes (CCR) in 1978 which was a generalized form of Farrell’s (1957) method in terms of multi-input and multi-output vectors. Their method is well known as “ Data Envelopment Analysis” or DEA. But their approach of measuring efficiency confounds the true technical efficiency score with uncontrollable noise (Charnes, Cooper, & Rhodes, 1978). Further developments in DEA were incorporated by Varian in 1985. He brought improvements in DEA by treating the deviations as having stochastic characteristics and split them into two components of technical efficiency and random noise (Varian, 1985).

The Free Disposal Hull (FDH) model, introduced by Deprins et al. (1984), was originally designed as an alternate to DEA models. In FDH approach only strong (free) disposability of inputs and outputs is assumed by relaxing the convexity assumptions of DEA models. FDH models were initially treated as DEA models under variable returns to scale (VRS). The FDH models are traditionally represented as mixed integer linear programming (MILP) problems. Further extensions in production frontier estimation are multi-equation models based on production, utility, cost or profit function specifications. Such extensions include the work of Kumbhakar (1987); Battese, Coelli and Colby (1989).

In the decade of 1990s, the literature on TE expanded with the growing use of Z-variables in the application of Stochastic Frontier Approach (SFA).

Previously, researchers used “ auxiliary” or “ two-step” regression on a set of socioeconomic, institutional and policy variables, so-called Z-variates to observe the effect of such variables on TE scores. A new method proposed by Wang and Schmidt allows a “ one-step” procedure for calculation of TE and inspect effects of such Z-variables (Wang & Schmidt, 2002).

Kalirajan and Obwona (1994) suggested another approach for modeling production behavior and technical efficiency of any production unit, known as “ Stochastic Varying Coefficient Frontier Approach” or SVFA. Under this method, like DEA, the potential output is estimated by allowing TE to vary by each individual input. Thus it makes comparison between firm’s performances easier in a sample of firms. It also facilitates to identify a benchmark of an excellent performing firm in terms of best practice in a sample (Kalirajan & Shand, 1999).

A recent approach, different from other sampling theory models, is “ Bayesian Approach” (BA). The approach treats the uncertainty concerning which sampling method to use by mixing over a number of competing a-priori inefficiency distributions with a-posteriori model probabilities as weights. This approach overcomes the criticism of imposing a-priori distributions on disturbance term as in SFA. But in Bayesian Approach, like SFA, the potential output to estimate TE varies over all inputs taken together. It also differentiates random effects and fixed effects issue for panel data (Kalirajan & Shand, 1999).

Developmetns are being made on the methods to make them more, efficient, flexible, easily computable and more policy oriented. Especially Bayesian and FDH approaches need more modifications and specifications.

Efficiency Studies in Developing Countries' Agriculture and Associated Factors

Here we cite some literature on efficiency estimates in agriculture sector of some developing countries with our main focus being on Pakistan. The findings regarding average efficiency scores and their relationship between different factors are summarized in the following paragraphs.

Shapiro (1983) examined TE of Tanzanian cotton farmers using a Cobb-Douglas production frontier. His findings yielded an average TE of 66 percent leading rejection of Schultz's (1964) hypothesis.

Balbase and Grabowski (1985) invested TE in Nepalese agriculture. His findings yielded 84 percent and 67 percent TE scores for rice and maize farms respectively. His analysis showed that nutrient levels, farmer's education and income were significant factors influencing TE.

Kalirajan and Shand (1985) examined TE of paddy farms in Indian state of Tamil Nadu. Their study proved non-formal education as significant positive factor in enhancing efficiency levels of farmers.

Ali and Flinn (1989) have used a modified trans-log stochastic profit frontier to investigate profit efficiency of Basmati rice farms in Pakistan. They identify education, credit, late application of fertilizer and water shortage as key factors in profit losses.

Ali and Chaudhary (1990) estimated efficiency for 220 farmers in Pakistani Punjab. According to his findings the average technical, allocative and economic efficiency were 84%, 61% and 51% respectively.

Hussain (1991) analyzed efficiency in Punjab province of Pakistan. His results showed a TE score ranging from 80 percent for rice region and 87 percent for sugarcane region.

Bravo-Ureta and Evenson (1994) analyzed efficiency for 101 cassava and 87 cotton farmers from Eastern Paraguay. His findings showed 58%, 70% and 41% technical, allocative and economic efficiency scores respectively for cotton farmers. Whereas the corresponding figure for cassava growers were 59%, 89% and 52% respectively. His results evidenced farmer's age, education, farm size, extension contacts and credit availability as significant factors influencing efficiency level of farmers.

Another study conducted by Ali, Parikh and Shah (1994) in NWF province of Pakistan by using both behavioral and stochastic cost frontier functions. Among socioeconomic variables, farmer's age, farm size, land fragmentation and subsistency were showing significant influence on inefficiency levels.

Ahmed et al. (2002) have analyzed TE of wheat growers in three provinces of Pakistan using a stochastic frontier production approach. The results yielded on average 32 percent losses due to technical inefficiency. The variables of age, education, extension services, farm to market distance, farm size, and credit availability had significant influence on efficiency levels of farmers in the provinces. He also found that wheat farmers in Punjab were technically more efficient (70%) than their counterparts in Sindh (66%) and NWFP

(63%). Tenants were technically more efficient than the owners and owner-cum-tenants.

Dhungana et al. (2004) have used Data Envelopment Analysis approach to examine efficiency of Nepalese rice Farmers. The results revealed that 76, 87 and 66 percent technical, allocative and economic efficiency levels were achieved by farmers. The factors contributing in inefficiency were excessive use of input resources, farmers' level of risk attitude, manager's age and gender, education and family labour endowment.

Hassan and Ahmed (2005) examined TE of wheat growers in a mixed farming system of Punjab province in Pakistan using a C-D production function. The mean TE was recorded about 94 percent. The key influencing factors of efficiency were education, timely cultivation of crops, credit availability, sowing patterns and water availability.

Bashir and Khan (2005) have conducted an efficiency analysis of 200 wheat farms in Northern region of Pakistan. They found high variation in yields of sample farms showing an average allocative efficiency of 72 percent in the study area. Farmers' awareness, education level, farm size and level of fertilizer used were significant factors depriving farmers to achieve their optimum level of profits.

Lambarraa et al. (2006) examined TE and productivity growth in the Spanish Olive sector. They found that farmer's age, farm location; tenure regimes of land and organic nature of farming techniques affect significantly the level of efficiency.

Mari and Lohano (2007) have analyzed TE of onion, tomato and chili farms in Sindh province of Pakistan. The mean TE was found to be 83 percent, 74 percent and 59 percent for chili, tomato and onion farms respectively.

A detailed study on TE of Russian agriculture has been conducted by Brock et al. (2007). They found interesting results under three organizational farming regime; i. e. peasant farming, large corporate farming and household plots. The TE rankings were highest for household plots (81%) followed by corporate farms (74%) and peasant farms (70%). The peasant farms were least efficient.

Analyzing efficiency of Nigerian food crops, Ajibefun (2008) has applied both SFA and DEA approach. He found only slight variation in average TE computed by both methods, i. e. 68 percent by SFA and 65 percent by DEA. Significant influencing factors were farmer's age and education level.

Kilic et al. (2009) have investigated TE of hazelnut production in Samson province of Turkey. Their study showed an average efficiency of 73. 5 percent. Farmer's education level and farm fragmentation were found as significant factor determining TE.

A very recent work by Monchuk et al. (2010) on TE in China's agriculture reveals that heavy industrialization and large percentage of rural labour force in agriculture sector tend to reduce TE. He suggests that air and water pollution have negative effects on agriculture production; and growth of non-primary agriculture may lead to efficient use of labour resources.

Factors Affecting Technical Efficiency

There are various socioeconomic, infrastructural, institutional and policy factors that tend to influence technical efficiency of farmers, thereby depriving them from achieving a potential output from their available resources. Identification and probable solutions of such factors had been the focus of researchers and policy makers' through decades. A summary table of the work of different researchers showing TE of different crops and significant factors affecting level of TE is given in Table 2. 1

Yield Gap

Yield gap is the difference between the yields of the experimental station by researchers and yield from farmers plot. According to Gomez (1977), yield gap appears in two ways (see Figure 2. 2);

The yield gap between maximum yield of research station and potential farm yield. This gap emerges into the system due to the environmental factors (climate, rainfall, humidity, sunlight etc) and non-transferable technology to farmers' fields from the research station.

Second type of yield gap is the difference between potential farm yields to that of the actual farm yield gained by the farmer. This difference arises from the different biological and socio-economic factors.

This study of these gaps is particularly important in the context of research and arises some questions that whether the research methodologies, technologies, environment, equipments and capital costs utilized at research station are appropriate to farmers' field conditions? Whether the recommended technology is complete? Whether this can address or takes into consideration the less favorable socioeconomic, bio-physical and environmental conditions of rain-fed and resource-poor marginalized farmers (Dahal, 1996)? The process of estimating technical efficiency gaps should be taken in a systematic and realistic way. It is necessary to consider the farmers specific farm trials rather than the trials conducted at the research stations.

Role of Marketing in Rural Economy

Farmers consider themselves as “ price takers” and think that they have no control over prices and are bound to accept whatever the price is offered. They do not know how to capture new markets nor how market demand and buyers’ preferences are changing and which products are to grow to gain more profit from their produce. Farmers generally have knowledge and skills in agriculture production techniques but marketing needs new skills, techniques and sources of information. Farmers armed with newest business and marketing skills will have better profit margins (Dixie, 2005).

Rural businesses include input suppliers, product buyers, transporters, storage companies, processing companies and wholesalers. These intermediaries are often believed to exploit farmers and making unfair profits. Although they try to maximize their profit yet it is to accept that without these intermediaries farmers would not be able to link with input and output markets and neither they would be able to sell their produce.

Role of Marketing in Consumer welfare

As farmers’ desire is to receive higher prices, consumers desire to pay lower prices. Farmers want to be paid as much share of consumer price as possible. These two conflicting goals balance when there is an efficient and low-cost marketing chain. Consumers' preferences are constantly developing particularly in the case of horticulture crops. They need a marketing system that can respond to their changing demands and tastes. The marketing system should supply the volumes, variety and quality products that consumers demand.

Fruits Marketing System in Pakistan (Aujla et al)

Marketing includes a series of inter-connected activities involved in the flow of products and services from the point of production to the point of consumption at a profit. An efficient marketing system guarantees sustained agricultural growth as it affects both producers' income and consumers' welfare (Aujla, Abbas, Mahmood, & Saadullah, 2007). The marketing of fruits in the Pakistan is supply based. Once a producer brings his produce to the market, the prices are decided by large traders at the spot such that he is bound to accept the prevailing prices. Most of the times the producers have to dispose off their commodities at throwaway prices (Hanif, Khan, & Nauman, 2004).

Several factors influence the efficiency of fruit marketing that include high perishability, seasonality, low quality, uneven prices and location of the products, the physical handling of produce and the institutional arrangements for facilitating these activities. The existing marketing system in Pakistan consists of assembly, wholesale and terminal markets, which are briefly discussed below:

Assembly Markets

Assembly markets are situated close to horticulture farm gate, generally situated in small towns or sub-districts, where farmers bring their major portion of marketable surplus for sale to the shopkeepers, traders and retailers present in these markets. Most of the transactions in assembly markets involve small quantities of produce. Traders in assembly markets are not approved by any government agency, although in some cases town committees charge an entry fee from traders. Usually, these traders maintain no systematic record of transactions. The price formation is simple and based on direct negotiation between the traders and the farmers. Because the quantities involve small bulks the farmers may not mind small price differentials.

Wholesale Markets

Wholesale markets are essential components of any marketing system, especially for horticulture crops because these markets provide farmers effective and profitable marketing outlets for their products. Adequately located, sized and managed wholesale markets serve as a basic instrument for promoting competition and help to improve consumers health and food quality control (FAO, 2001).

Wholesale markets in Pakistan are usually located in a district town or a major sub-division town. These markets are the main assembly centers for the fruit and vegetable surplus of surrounding areas. These markets have better transportation, storage, communication and working conditions than those in the assembly markets. The example of wholesale market in Balochistan is that of Quetta, where the surplus fruit produce of nearby districts are supplied. Wholesale markets have permanent auction floors and offices built by traders (commission agent) who hold an official permit for their activities. Each trader has sufficient space in the market to store produce for a few days or for longer periods at a nominal charge. Traders keep records of their daily transactions and report them to the Market Committee. Market participants in wholesale markets including commission agents, wholesalers, retailers, shopkeepers and weighing men are also registered and licensed by Market Committees. Introduction of these measures have resulted in some improvements in these markets. Commission agents in wholesale market, charged 8 to 10 percent commission on the sale revenue (Hussain & Abid, 2005). The major players in the wholesale market are commission agents, wholesalers, retailers and shopkeepers.

Terminal Markets

Terminal markets are generally situated in large urban centers. Most of the marketable surplus of agricultural commodities is ultimately routed to these markets. The Karachi market is one of the best examples of this kind of market in Pakistan. Foreign trade is another reason for the flow of the marketable surplus to this market. Traders in terminal markets are usually wholesalers who supply agricultural products to firms, industries and exporters. The majority of traders are buying agents, who buy from other wholesale markets through their agents or directly when the produce is brought there from other regions. This market is well equipped with traders who are well established and mostly depending on supplies from growers and other wholesale markets. They have access to all modern facilities for approaching their agents in lower level markets. Many traders have their own trucking companies. Telephone and telegraph services are easily available for them.

Fruit Marketing Channels in Pakistan

Khushk and Smith 1996

Khushk and Smith (1996) have done a nice and detailed study of fruit marketing channels in Pakistan by concentrating particularly on mango production in Sindh province. According to them, agricultural marketing channels refer to the outlets or routes through which commodities pass to reach final consumers. As produce moves along the marketing chain, its price increases because of opportunity cost incurred by each intermediary (Dixie, 2005). The existing fruit marketing channels in Pakistan by ……. are presented in Figure

-
-
-
-
-

Figure 2. 3 Marketing Channels for Fruits in Pakistan

The marketing channels functionaries common in the country are;

Producer

The fruit growing farmers are dispersed geographically in the country. Majority of producer sell the harvesting rights of their orchards to contractors at the flowering or in hanging fruits stage because they do not want to be involved in marketing complications. Also the farmers do not do not want to take the risk of price and income variation due to perishability, quality damage, and price seasonality. In addition, Khushk and Smith (1996) found another important reason reported by farmers is the lack of knowledge of marketing. commission agents are biased towards farmers than contractors and do not want to transfer market price information to farmers or provide them other facilities, like informal credits, transportation or information access at the market-place. By this way commission agents control the supply, demand and prices of market (Khushk & Smith, 1996; Ali, 2004; Aujla, Abbas, Mahmood, & Saadullah, 2007).

Contractor

The contractor plays a main role in the marketing of fruits. He has close contacts with commission agents in the wholesale and terminal markets. While contracting an orchard, the contractor estimates its yield and considers the expected costs to be incurred for supervision, labour, transportation, and marketing. Khushk and Smith (1996) report that more than 95 percent of mango contractors in Sindh province of Pakistan obtained loans from commission agents to pay the initial installments to the mango farmers and to pay an advance for labour and packing material. Once a contractor receives loan from commission agent, he is obliged to supply the produce to that commission agent.

Commission Agent

Commission agents act as a link between contractors in the field and wholesalers or retailers at wholesale market. They usually have their own transport companies and have offices and staff at wholesale markets of big cities, equipped with all communication facilities. They maintain contacts with market committees, market associations, wholesalers and retailers and influence the prices in fruit markets of Pakistan (Ali, 2004).

Wholesaler

Wholesalers perform their business in wholesale or terminal markets of the country. They do business with large quantities of farm products and deal in several commodities like vegetables, fruits and other agricultural produce within interregional markets and also supply produce to processing industries, exporters, and retailers according to their demand. They maintain contacts with commission agents in wholesale markets and retailers in the local area. Wholesaler usually purchase fruit from the commission agents at open auction and sell in smaller quantities to the retailers and consumers. They mostly buy from the commission agents on a credit basis, and about one week after selling that quantity, they pay the commission agents. Some wholesalers also act as commission agents (Khushk & Smith, 1996; Ali, 2004; Zulfiqar, Khan, & Bashir, 2005).

Retailer

Market activities come to end with the retailers. They buy and sell small quantities according to the demand of consumers in the area. A small number of fruit retailers occupy small shops in the main fruit markets or in the town. Moreover, a number of retailers are found standing at focal places of a town, particularly railway stations, bus stands, vicinity of courts, schools, and hospitals. Among fruit retailers there is a high degree of competition.

Retailers buy fruit from the wholesalers on a 24-48 hour credit basis (Khushk & Smith, 1996; Ali, 2004; Zulfiqar, Khan, & Bashir, 2005).

Importance of Market functionaries / Intermediaries

Although a heavy literature is found on exploitative behavior of market intermediaries towards agriculture producers, especially in developing countries such as Pandit et al. (2005) Aujla et al. (2007), Khushk and Smith (1996) and many others, yet their role cannot be ignored (Dixie, 2005). It is often mis-understood how important traders are in taking agriculture produce from farm to the market. Their importance becomes more critical in case of fruits which are highly perishable in nature and need quick supply. The more dynamic the fruit trading sector leads greater competition among traders and greater volumes of produce taken out of rural farm lands resulting, ultimately, high income returns to the farming community. Farmers Selling directly to consumers does mean higher profits but also greater risks. Market traders accept that risk such as non-payments, price decrease and marketing and handling losses (Khushk & Smith, 1996). Therefore the intermediaries should be encouraged, not criticized (Dixie, 2005; Pokhrel, 2005).

Marketing Margin Analysis

“ Marketing margins” or “ farm-to-retail price spread” are some functions of differences between farm-gate prices and retail prices, intended to measure the opportunity cost of providing marketing services including buying, grading, packing, transporting, storage, and processing (Khushk & Smith, 1996; Wohlgenant, 2001). The prices paid to the rural sellers at farm-gate are much lower. But as the product moves along the production-marketing chain, its price increases such that the retailers achieve the highest price (see Figure 2. 3).

The farm-to-retail price spread of fruits in Pakistan is con