Measurement of productive efficiency of tomato growers in Peshawar, Pakistan

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Abstract: The present paper estimates the technical, allocative and economic efficiency of tomato growers. The study was conducted in two villages, namely, Tarnab and Akbarpura of the District Peshawar, the Khyber Pakhtunkhwa province, Pakistan. The data were collected by conducting a farm level survey of 300 tomato growers in the study area. The findings show that there was a big gap between the maximum and minimum technical efficiency indices, with an average technical efficiency index of 66%. There was also a huge gap between the highest and the lowest index of allocative efficiency of tomato growers. Economic efficiency indices also varied significantly. The study concluded that the farmer education, extension visits, age and access to credit were the significant determinants of these efficiencies. One of the most important policy implications of this study is that there is enough potential to increase the present level of efficiencies for tomato production in the study area.

Key words: equity and efficiency, economics, developing countries, economic change, economic development

Agriculture is the backbones of the economy of Pakistan, it is the major contributor to its gross domestic product (GDP). It accounts for 22% of the country's GDP and provides employment to about 45% of the total employed labour in the country. Crop production is a major contributor to the value addition in the agricultural sector. Major and minor crops constitute 33.4% and 12%, respectively, of the overall value addition in agriculture (Government of Pakistan 2009). In spite of its pivotal importance in the economy of Pakistan, the contribution of agriculture in GDP is gradually decreasing over time. The sluggish pace of agricultural growth has led to a low income, low savings and low investment opportunities in rural economy. As a result, the pace of development in the non-agricultural sectors has also declined which in turn has resulted in the lack of employment opportunities as well as in the increase in poverty in rural areas.

Some studies claim that the strategy for agricultural growth should be based on enhancing the crop yields, especially for small farmers. There is sufficient empirical evidence that small-scale farming provides jobs to the unemployed labour force (Bravo-Ureta and Pinheiro 1993, 1997; Bravo-Ureta and Evenson 1994). Researchers and policy planners, therefore, have given much attention to the use of new technologies for enhancing the crop yields and the income of households. However, in recent years, the use agricultural technology is already high. This calls for the increase in productivity through the optimal and efficient use of the available technologies (Bravo-Ureta and Pinheiro 1993).

Tomato is an important vegetable in Pakistan in general and in the study area in particular, which is used as food item on the daily basis. It can be considered as the most ubiquitous of all vegetables. It is mostly used as a fresh vegetable and it can be used for making different products as well. The study aims to measuring the possibilities of the productivity gains from enhancing the efficiency of tomato farmers. The study aims at providing guidance to various stakeholders on how to increase the tomato production by identifying the extent by which the tomato production efficiency could be raised with the available technology and resource base in Pakistan. In order to provide policy implications, the efficiency measurements will be decomposed into technical, allocative and economic efficiencies using stochastic efficiency decomposition frontier analysis.

MATERIAL AND METHODS

Study area

The two selected villages, namely, Tarnab and Akbarpura, constitute the area of this study. These villages are located in close vicinity of Peshawar. Peshawar is the provincial capital city of the KPK province. The study area is situated in the North-Western part of Pakistan, which is famous for the cultivation of major and minor crops as well as vegetables and fruits. Tomato is the most important vegetable in this area. It supplies all kinds of vegetables to urban market of the Peshawar city as well as other areas of the country. Because of the favourable climatic conditions, the area is well suited for the production of food crops including wheat and maize; perennial crops like sugar cane; all kinds of vegetables and fruits. The area is also irrigated. The fertility of the soil was also increased by heavy floods of summer 2010. The production of tomatoes and other vegetables played a key role in the rehabilitation and reconstruction of the rural economy of the flood-affected area. Farmers of area have small land holdings in the range of 0.5–1.5 hectares with more than 50% of farmers cultivating up to 0.35 hectares of land.

Collection of data and sampling procedure

In order to collect data for this study, a detailed interview schedule was designed which had questions about the socio-economic background of the sample households, age and education, income, and landholdings of the respondent. The interview schedule also contained questions about tomato production, the cost of tomato production on various inputs used in tomato production, prices of variable and fixed input as well as of tomato production which we needed for the analysis. The interview schedule was pretested before the actual data collection and revised based on the feedback from the sample respondents. A multistage sampling technique was used. In the first stage, the villages of Tarnab and Akbarpura were purposely selected because these villages are more suitable for growing tomatoes. The land in these villages is fit for growing the best variety of tomatoes. Following this, we identified only those households who were specifically tomato growers. Then a list of farm households, who were tomato growers, was prepared, from which 300 households were selected by the simple random sampling technique. During the interview, the background of the study was explained to the respondents and a rapport was generated for the purpose of collecting quality data. The respondents were cooperative in giving information. In case that some respondent refused to give the data, then the next household was selected for the interview. The data collection took two-month time (June–July) in 2011. For the data analysis, we used the Statistical Package for Social Sciences (SPSS) as well the LIMDEP.

CONCEPTUAL FRAMEWORK

The concept of productive efficiency was first introduced by Farrell in 1957 in his seminal publication (Farrel 1957), in which he argued that there were two components of efficiency[1]: technical efficiency (TE) and allocative efficiency (AE). According to Farrell's methodology, economic efficiency (EE*)* is equal to the product of TE and AE, where TE is associated with the ability to produce on the frontier isoquant, while AE refers to the ability to produce at a given level of output using the cost-minimizing input ratios. In other words, technical inefficiency reflects the deviations from the frontier isoquant, and allocative inefficiency is related to the deviations from the minimum cost input ratios. Thus, EE is defined as the capacity of a firm to produce a predetermined quantity of output at the minimum cost for the given level of technology (Farrell 1957; Kopp and Diewert 1982). An economically efficient firm is the one which is technically as well as allocatively efficient. Further detail about the conceptual framework can be seen in another study (Khan 2012).

ANALYTICAL FRAMEWORK AND MODEL SPECIFICATION

According to a seminal article (Kopp and Smith 1980), functional forms have a limited effect on the empirical efficiency measurement. Another study (Battese 1992) has reported that any empirical studies relating to developing countries have used the Cobb-Douglas functional forms. The Cobb-Douglas functional form also meets the requirement of being self-dual, allowing an examination of economic efficiency. In this study, the following Cobb-Douglas functional form was selected to model tomato production technology:

[1]According to Farrell (1957), "TE is the ability of a firm to produce the maximum possible output from a given set of inputs or it is the ability of a firm to use the minimum inputs for a given level of output. The former is called input oriented measures and the latter is known as output-oriented measures of technical efficiency. AE is the ability of a firm to use inputs in the optimal proportion, given their respective prices and the production technology. The use of an input is allocatively efficient if the value of marginal product is equal to its price."

$$Y_i = \beta_0 \times \prod_{i=1}^{4} X_i^{\beta_i} \times e^{(V_i - U_i)} \quad (1)$$

which, when linearized, becomes:

$$\ln Y_i = \ln \beta_0 + \beta_i \sum_{j=1}^{4} \ln X_{ij} + \varepsilon_i \quad (2)$$

where Y_i is the output of farmer i, X_{ij} is the j input used by farmer i, and ε_i i is a "composed" error term. The error term (ε_i) is explained as $\varepsilon_i = (v_i - u_i)$, $i = 1, 2, ..., N$. v_i is a two-sided ($-\infty < v < \infty$) normally distributed random error ($v \sim N[0, \sigma_v^2]$) that represents the stochastic effects outside the farmer's control (e.g., weather, natural disasters, and luck), measurement errors, and other statistical noise. u_i is a one-sided ($u \geq 0$) efficiency component that represents the technical inefficiency of the farm. In other words, u_i estimates the shortfall in output Y_i from its maximum value given by the stochastic frontier function:

$$\ln Y_i = \ln \beta_0 + \beta_i \sum_{j=1}^{4} \ln X_{ij} + v_i \quad (3)$$

This one-sided term of distribution can be half-normal, exponential, or gamma (Aigner et al. 1977). In this study, it is assumed that u_i is a half-normal distribution ($u \sim N[0, \sigma_u^2]$) as it is typically used in the applied stochastic frontier literature. The two components v_i and u_i are also assumed to be independent of each other.

In Equations 1–3, βs are unknown parameters to be estimated, X_1 = labour input; X_2 = other variable cost (e.g. herbicide, insecticide and fertilizer); X_3 = access to credit; X_4 = farm size in ha; u_i = the specific technical efficiency factor for farm i; v_i = a random variable for farm i.

The cost frontier for tomato farms dual to the production frontier can be expressed as:

$$\ln C_i = \alpha_0 + \sum_k \alpha_k \ln P_{ik} + \gamma \ln Y_i^* + (v_i + u_i) \quad (4)$$

where C_i = the minimum cost to product output Y_i, P_{ik} = vector of k^{th} input price, α, γ = vector of parameters. Further, P_1 = the average wage rate per man days of labour, P_2 = the average variable cost (of herbicide, insecticide and fertilizer), P_3 = the cost (rate of interest) on credit, P_4 = the average land rent per hectare and Y_i = as earlier defined above. βs, αs, γ = the parameters to be estimated. The frontier functions (production and cost) are estimated through the maximum likelihood methods.

The model for the technical, allocative and economic inefficiency effects was specified as follows:

$$\Psi_{ti,ai,ei} = \omega_0 + \omega_1 X_5 + \omega_2 X_6 + \omega_3 X_7 + \omega_4 X_8 \quad (5)$$

where $\Psi_{ti,ai,ei}$ represents inefficiency effects, the subscripts *te, ae*, and *ee* stand for technical, allocative and economic inefficiency effects. Ψ_0 = the constant of the inefficiency model, X_5 = the farmer formal schooling, (years); X_6 = the number of extension visits; X_7 = access to credit (ratio of credit used and credit required); and X_8 = the age of farmers (years). We used the maximum likelihood estimation technique for estimating *te*, *ae*, and *ee* using the frontier production function.

RESULTS AND DISCUSSION

Maximum likelihood estimates of the frontier production function

Table 1 gives the summary statistics of various variables used in the stochastic production and cost function analysis. The maximum likelihood estimates (MLE) of Equation 2 are given in Table 2. In order to check whether technical inefficiency effects are absent, we may use the important test. The important parameter of log-likelihood in the half-normal model is $\lambda = \sigma_u/\sigma_v$. If the value of λ is equal to 0, there are no technical inefficiency effects and all deviations from the frontier are due to noise (Aigner et al. 1977). The estimated value of $\hat{\lambda}$ = 0.688 is significantly different from 0 and the null hypothesis that that there are no inefficiency effects is rejected at 5% significance level (in terms of the Z-statistic ($Z = \hat{\lambda}/se\hat{\lambda}$ = 2.05 which exceeds the critical value of $Z_{0.05}$ = 1.96 implying that there exist inefficiency effects among the tomato growers in the study area. The ratio of the standard error of u (σ_u) to the standard error of v (σ_v), known as lambda (λ), is 0.688. Based on λ, we can derive gamma (γ) which measures the effect of technical inefficiency on the variation of the observed output ($\gamma = \lambda^2/(1 + \lambda^2) = \sigma_u^2/\sigma_\varepsilon^2$). The estimated value of γ is 0.47, which means that 47% of the total variation in tomato output is due to technical inefficiency.

The estimated coefficients show the relative change in tomato output (Y) due to a percentage change explanatory variable. These estimates show the relative importance of various inputs in tomato production in Northern Pakistan. The coefficient of labour input was highest implying that it is the most important explanatory variable in tomato production which showed that the tomato production increases by 26% for each extra percentage of labour. This may also be due to the reason that tomato is a labour inten-

Table 1. Descriptive statistics of variables used in stochastic production and cost function analysis

Variable	Average	Standard Deviation	Min.	Max.
Tomato yields (kg/ha)	10 546	3.8	7 400	14 200
Farm size (ha)	0.50	2.3	0.23	0.84
Fixed cost (Rs/ha)	14 869.6		9 663.1	22 708.4
Variable cost[1] (Rs/ha)	9 913.0		6 442.1	15 138.9
Credti (Rs)	15 000	–	10 000	25 000
Farmer education	6	–	0	12
Extension visits	5	1.6	2	8
Age	42	11.9	28	65
Gross revenues (Rs/ha)	**74 595.0**	–	**53 622.8**	**97 608.5**
Net revenues (Rs/ha)	**49 812.4**	–	**37 517.6**	**59 761.2**
Cost of land input	5 480.9	35	4 003.2	6 993.2
Cost of labour input	6 195.0	39	3 941.4	8 031.0
Cost of capital	13 106.7	60	8 160.6	22 823.1
Total production cost (Rs/ha)	24 782.6	–	16 105.2	37 847.3

[1]Variable cost (VC) includes cost of herbicide, insecticide, chemical fertilizers, farm yard manure and seed/nurseries, cost of farm tools used for tomato growing
1 USD = Pak. Rs 85

sive vegetable in which few improved technologies (chemical and mechanical inputs) are employed. The estimated coefficient of capital was the lowest (0.05) but statistically significant at 0.05, implying 5% change in tomato production due to an additional percentage change in capital. Coefficients of variable costs and the farm size were also significant at 0.05. For the estimated Cobb-Douglas cost frontier model (Equation 13), the coefficient of land expenses was the highest. This may be because access to land is still hampered by the type of the tenure system and farm size in the study area. It can be inferred from this finding that land could be described as scarce in the state. All other coefficients had positive signs and are significant at 5% level (Table 2).

Technical efficiency

Technical efficiency indices varied significantly, with the technical efficiency index ranging from 45% to 85% with mean at 66%. Table 3 shows that the modal class (71–80%) had a better technical efficiency than the lowest class (11–20%). This could be because these farmers had relatively larger farms, had a relatively higher level of former schooling, were comparatively younger, and had a higher number of contacts with extension workers. This trend was also found in the highest class (81–90%). None of the respondents had a technical efficiency of 100%. This implied that the room for improvement in tomato production was existent in the study area with the given resource base and available technology. Some other studies have a similar kind of findings (Abdellah et al. 2006; Mari and Lohano 2007; Alam et al. 2012).

Allocative efficiency

The indices of allocative efficiency also varied widely, with an average of 56%. It can be seen in Table 4 that the modal class (51–60%) had a higher allocative efficiency than the lowest class (11–20%) because farmers in the modal class had a higher level of formal education, were younger, and had more visits to the extension department and had been in the tomato production for a longer time. These farmers, therefore, can be thought of as the agents for the development of tomato production. Similarly, none of the sample farmers had a 100% allocative efficiency index. This implied that resources could be allocated to their best alternative uses and prices could as well be allowed to perform their allocative functions in the use of inputs.

Economic efficiency

The range of economic efficiency indices is also high implying a huge gap between the lowest and

Table 2. Maximum likelihood estimates for tomato farms using the Cobb-Douglas frontier production and cost functions

Variable	Parameters	Coefficients	Standard errors
Production analysis			
Intercept	β_0	3.83	0.37***
ln labour	β_1	0.26	0.09***
ln VC	β_2	0.15	0.06**
ln capital	β_3	0.05	0.021**
ln farm size	β_4	0.11	0.05**
Function coefficient		0.57	
Ratio of the SE of u to the SE of v ($\lambda = \sigma_u/\sigma_v = 0.31/0.45$)	λ	0.688	0.334**
Total variance ($\sigma^2 = \sigma_u^2 + \sigma_v^2$)	σ^2	0.299	
Log livelihood function	–	–0.6983	
Cost analysis			
Intercept	α_0	2.67	1.42
ln P_1	α_1	0.18	0.09**
ln P_2	α_2	0.09	0.04**
ln P_3	α_3	0.21	0.09**
ln P_4	α_4	0.33	0.15***
ln output (Y)	γ	0.18	0.09**
Ratio of the SE of u to the SE of v ($\lambda = \sigma_u/\sigma_v$=0.37/0.49)	λ	0.75	0.35**
Total variance ($\sigma^2 = \sigma_u^2 + \sigma_v^2$)	σ^2	0.57	
Log livelihood function	–	–0.73	

*** and ** shows significance at 0.01 and 0.05, respectively

highest economic efficiency indices, with a mean of 35%. Farmers in the modal class (31–40%) had in the average larger landholdings, had a higher level of formal schooling, less experience, and were relatively younger than the farmers in the lower class. This shows that there is a great potential that could

Table 3. Tomato growers classified by technical, allocative, and economic efficiency

Efficiency level	Technical efficiency		Allocative efficiency		Economic efficiency	
	no.	%	no.	%	no.	%
11–20	1	1.6	1	1.6	1	1.6
21–30	1	1.6	2	3.3	9	14.7
31–40	3	4.9	7	11.5	15	24.6
41–50	10	16.4	9	14.7	13	21.3
51–60	12	19.7	25	41	10	16.4
61–70	15	24.6	10	16.4	10	16.4
71–80	17	27.9	5	8.2	2	3.3
81–90	2	3.3	2	3.3	1	1.6
91–100	–	–	–	–	–	–
All	61	100	61	100	61	100
Mean	66		56		35	
Minimum	45		25		18	
Maximum	85		73		55	

Table 4. Determinants of productive inefficiencies

Factor	Technical inefficiency Ψ_{TI}		Allocative inefficiency Ψ_{AI}		Economic inefficiency Ψ_{EI}	
	coefficient	t-ratio	coefficient	t-ratio	coefficient	t-ratio
Constant (ω_0)	2.83	7.64^{***}	2.60	5.4^{***}	2.14	7.64^{***}
Farmer Edu (ω_1)	–0.21	-2.1^{**}	–0.19	-2.1^{**}	–0.16	-2.08^{**}
Ext. Visits (ω_2)	–0.18	-2.25^{**}	–0.17	-2.25^{**}	–0.13	-2.21^{**}
Credit (ω_3)	–0.04	-2.10^{**}	–0.04	-2.1^{**}	–0.04	-2.07^{**}
Age (ω_4)	0.11	2.2^{**}	0.09	2.0^{**}	0.03	1.8

be exploited by the farmers of the area by enhancing their tomato production and profit with the available technology and resource base only by improving the utilization of the production factors.

Determinants of efficiencies among tomato growers

Table 4 also shows various factors that determine productive efficiencies of tomato growers in the study area.

Formal education of farmers

Education is an important factor that sharpens the managerial capabilities of farmers. It helps farmers in timely decision making. Education of farmers may enable them to make a good use of information about production inputs, thus improving the efficient use of inputs. The algebraic sign of the estimated coefficient of farmer education was negative and statistically significant at 0.05. This means that as the education of farmer increases, the inefficiency effects decrease, which alternatively means that the farmer education and technical efficiency go side by side. Thus, our study found out that the higher is the level of the formal schooling of farmers, the higher is the technical, allocative and economic efficiency. Further, among the educated farmers, those with a high school education were more efficient compared with other categories. However, our findings are in disagreement with some earlier studies (Page and John 1984; Mari and Lohano 2007). These studies reported a negative relationship between technical efficiency and formal education.

Extension visits

The estimated coefficient for extension visits had also a negative sign implying that extension visits affected the productive inefficiency negatively and it demonstrated that extension visits were an important factor in determining technical efficiency in the study area. Similar findings were also reported by other studies which found a positive relationship between farm level efficiency and the availability of extension services (Kalirajan 1981, 1991, 1999; Kalirajan and Flinn 1983; Kalirajan and Shand 1985; Bravo-Ureta and Evenson 1994; Alam et al. 2012).

Age

The estimated age coefficients were positive with respect to various production inefficiencies. These coefficients were statistically significant at least at 5%. This implied that age contributed positively to inefficiencies which, in other words, means that younger farmers were relatively more efficient than older farmers. This is an important finding, which means that younger farmers are comparatively more educated than the older farmers. Thus, it can be inferred from this finding that the younger and more educated is the farmer, the more technically and economically efficient he/she is. These findings are in agreement with a number of some recent studies conducted in others parts of Pakistan (Abellah et al. 2006; Fateh and Lohano 2007; Javed et al. 2010; Alam 2012).

Access to credit

Access to credit may enable farmers to purchase productive inputs on time. It may lead to higher productive efficiencies. The coefficients of access to credit were negative for production inefficiencies and were significant at 0.05. This shows that the higher the access to credit, the more efficient the farmer became. This is in line with Parikh and Shah (1994) and in disagreement with Okike (2001) which showed that receiving credit contributed to farmers' economic inefficiency. If production credit is invested on the farm, it is expected that this will lead to higher levels of output. Thus, access to credit is more likely to lead to an improvement in the level of technical and allocative efficiency.

CONCLUSIONS

This study has estimated the stochastic production and consumption frontier functions. It has predicted the farmers' productive efficiencies of 300 tomato growers in the villages of Tarnab and Akbarpura, the KPK province in Northern Pakistan. The Cobb-Douglas stochastic frontier production and cost functions were estimated with the maximum likelihood estimation method. The estimated productive efficiencies were explained by various socio-economic and demographic factors. The findings show that there was a wide gap between the highest and lowest technical efficiency indices, with an average technical efficiency index of 66 percent. There was not even a single farmer who had a technical efficiency of 100%. This implies that, using the subsisting resource base, an improved efficiency can still be achieved. Here was also a huge gap between the highest and the lowest index of allocative efficiency of tomato growers implying that there was a substantial loss in the net profit in tomato growing. Economic efficiency indices also varied significantly showing that there was a great potential for increasing the gross output and profit with the existing level of resource base. Regarding the sources of productive efficiencies, the study concluded that the farmer education, extension visits, age and access to credit contributed significantly and positively to these efficiencies. One of the most important policy implications of this study is that there is enough potential to increase the present level of efficiencies for tomato production in the study area. The study recommends that the Government of Pakistan should invest more in education in general and farmer education (formal as well as informal education) in particular, as the farmer education would reduce productive inefficiencies. Another policy implication of the study is that extension education has a direct relationship with efficiency. Therefore, the government should strengthen the extension services of its Agriculture Department, so that farmers have an easy access to it. This may help them in increasing the farm output and net profits.

REFERENCES

Abdellah A., Bakhsh K., Bashir A. (2006): Technical efficiency and its determinants in potato production function: evidence from Punjab, Pakistan. The Lahore Journal of Economics, *11*: 1–22.

Aigner D.J., Lovell C.A.K, Schmidt P. (1977): Formulation and estimation of stochastic frontier production function models. Journal of Econometrics, *6*: 21–37.

Alam A., Kobayashi H., Motsumura I., Ishida A., Esham M. (2012): Technical efficiency and its determinants in potato production: evidence from northern areas in Gilgit-Baltistan region. International Journal of Research in Management, Economics and Commerce, *2*: 1–17.

Battese G.E. (1992): Frontier production function and technical efficiency: a survey of empirical applications in agricultural economics. Agricultural Economics, *7*: 185–208.

Bravo-Ureta B.E., Pinheiro A.E. (1997): Technical, economic, and allocative efficiency in peasant farming: Evidence from the Dominican Republic. The Developing Economies, *35*: 48–67.

Bravo-Ureta B.E., Pinheiro A.E. (1993): Efficiency analysis of developing country agriculture: a review of the frontier function literature. Agricultural and Resource Economics Review, *22*: 88–101.

Bravo-Ureta B.E., Evenson R.E. (1994): Efficiency in agricultural production: the case of peasant farmers in eastern Paraguay. Agricultural Economics, *10*: 27–37.

Farrell M.J. (1957): The measurement of productive efficiency. Journal of the Royal Statistical Society, Series A (General*)*, *120*: 253–290.

Government of Pakistan (2009): Pakistan Economic Survey 2008–09. Finance Division, Economic Advisor's Wing, Islamabad.

Javed M.I., Adil S.A., Raza M.A. (2010): Measurement of technical efficiency of rice-wheat system in Punjab, Pakistan using DEA technique. Journal of Agricultural Research, *2*: 227–237.

Kalirajan K. (1981): An econometric analysis of yield variability in paddy production. Canadian Journal of Agricultural Economics*, 29*: 283–294.

Kalirajan K. (1991): The importance of efficient use in the adoption of technology: a micro panel data analysis. Journal of Productivity Analysis*, 2*: 113–126.

Kalirajan K.P. (1999): Frontier production functions and technical efficiency measures. Journal of Economic Surveys, *13*: 149–172.

Kalirajan K., Flinn J.C. (1983): The measurement of farm-specific technical efficiency. Pakistan Journal of Applied Economics*, 2*: 167–80.

Kalirajan K., Shand R.T. (1985): Types of education and agricultural productivity: a quantitative analysis of tamil nadu rice farming. Journal of Development Studies, *21*: 232–243.

Khan H. (2012): Measurement of technical, allocative and economic efficiency of tomato farms in Northern Pakistan. Journal of Agricultural Science and Technology B, *2*: 1080–1090.

Kopp R.J., Diewert W.E. (1982): The decomposition of frontier cost functions deviations into measures of technical and allocative efficiency. Journal of Econometrics, *19*: 319–331.

Kopp R.J., Smith V.K. (1980): Frontier production function estimates for steam electric generation. A comparative analysis. Southern Economic Journal, *47*: 1049–1059.

Mari F.M., Lohano H.D. (2007): Measuring production function and technical efficiency of onion, tomato and chilies in Sindh, Pakistan. The Pakistan Development Review, *46*: 1053–1064.

Okike I., Jabbor M.A., Smith V.K., Akinwumi J.W., Ehui S.K. (2001): Agricultural Intensification and Efficiency in West Africa Savannahs: Evidence from Northern Nigeria. Socio-economic and Policy Research Working Paper 33. ILRI, Nairobi.

Page M.J., John M. (1984): Firm size and technical efficiency: applications of production frontiers to Indian survey data. Journal of Development Economics, *16*: 29–52.

Parikh A., Shah M.K. (1994): Measurement of technical efficiency in the northwest frontier province of Pakistan. Journal of Agricultural Economics, *45*: 132–138.

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