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Technical Efficiency and Its Determinants in Food Crop Production: A Case Study of Farms in West Bank, Palestine

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ABSTRACT

In this study, farm level technical efficiency (TE) and its determinants were investigated. A stochastic Cobb-Douglas (CD) production frontier was used to provide estimates of input-oriented *TE* for a sample of 100 rain fed farms in two Palestinian governorates. Empirical findings showed that the estimated *TE* of the farms in the pooled sample ranged from 35.7 to 95.6%, with a mean value of 72.2%. This suggests that, on average, farms in Jenin and Tubas can potentially increase their productivity by as much as 28% through more efficient use of inputs. Analysis of the main determinants of *TE* suggested a positive relationship between farmers' level of education, experience, access to credit and extension services, and membership in a cooperative. We argue that access to credit and strengthening of capacity within the national extension system are critical areas of public policy concern in order to affect levels of agricultural production and productivity in the West Bank.

Keywords: Cobb-Douglas stochastic frontier model, Cross section data, Palestine, Rainfed farms.

INTRODUCTION

Most countries in the Middle East are characterized by low per capita income, high rates of poverty, and food insecurity. These characteristics are particularly prevalent in rural areas, where high population growth rates are placing increasing pressure on renewable and non-renewable resources, with growing concern for food security.

Agriculture remains a dominant sector of the Palestinian economy. It represents a major component of the economy's GDP, and employs a large fraction of the population. Agriculture in the Palestinian context is not merely an economic or income generating activity, rather, it is considered a major contributor to the protection of the land from confiscation and settlements, it provides food security, job opportunities for 13.4% of the total labor force, 8.1% to the GDP and 15.2% of total exports (Palestinian Central Bureau of Statistics, 2009). Despite the importance of the agricultural sector to the economy of Palestine, its performance has been unsatisfactory and it has been unable to fulfill a growing demand for food (PCBS, 2009). However, accelerating agricultural growth remains an important policy objective in Palestine where agricultural productivity is low (Ministry of Agriculture, 2010), population growth rates are high, and the ability to import food is severely constrained.

In Palestine, short- and medium-term development policies continue to recognize agriculture as an important sector, with priorities centered on food security initiatives and greater provision of employment opportunities. For the agricultural sector to play a central role in the economy, rapid growth in crop production and productivity is critical in terms of attaining a stated desire for

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attaining food self-sufficiency, which has been difficult to achieve despite expansion in agricultural land through a number of reclamation projects (MoA, 2010).

A program for enhancing food security and livelihoods for poor rural communities in Palestine is an important research for development initiative developed by the International Center for Agricultural Research in the Dry Areas (ICARDA) and the National Agricultural Research Center (NARC). This is funded by The Netherlands Government. Cultivated rainfed production is conducted on 86% of the total cultivated area, a percentage considered high when compared with water scarce countries such as Jordan (77%). Expansion in irrigated production on the remaining 14% of total cultivated land (MoA, 2010) continues to remain limited, largely given that Israel controls 82% of Palestinian groundwater resources in the West Bank (MoA, 2010).

Given a growing emphasis on increasing productivity and production of key field crops, a crucial role for efficiency gains in increasing agricultural output has been widely recognized in research and policy arenas. It is not surprising, therefore, that considerable effort has been devoted to the measurement and analysis of productive efficiency, which has been the subject of a myriad of theoretical and empirical studies for several decades since Farrell's (1957) seminal work.

This paper contributes to the limited literature on farm level efficiency measurement and explanation within the geographic region of interest by utilizing a stochastic frontier production model with technical inefficiency effects for cross section data. This approach has the advantage of simultaneously estimating parameters of the stochastic frontier and inefficiency models, given appropriate distributional assumptions associated with error terms. To the authors' knowledge, this is the first paper that provides empirical evidence on the sources of technical inefficiency on Palestinian farms through the employment of a stochastic frontier model.

There is no doubt that production efficiency has become a major topic of the economics of production on farms both at micro and macro levels for Palestinian political decision makers (MoA, 2010). Improvement in the *TE* of production is the first logical step towards considerably increasing crop production in this region. Thus, knowledge of the relative contributions of production factors to output growth and improvements in *TE* is crucial to help farm managers and policy makers to draw up appropriate policy measures and for efficient farms to have a better chance of surviving and prospering.

This paper examines the nature of *TE* and investigates the factors contributing to productivity improvement of food crop production on Palestine farms utilizing stochastic frontier models. A pre-requisite for enhanced efficiency is the identification of those factors that prevail at the farm level and which affect the efficiency of production. Understanding these factors and their implication on productivity and production will be of critical importance in the provision of information for the formulation of appropriate agricultural policies in Palestine, and with potential applicability to other countries within the region.

MATERIALS AND METHODS

Analytical Framework

Since the stochastic production frontier model was first, and nearly simultaneously, published by Meeusen and van den Broeck (1977) and Aigner et al. (1977), there has been considerable research aimed at extending the model and exploring exogenous influences on producer performance. Early empirical contributions investigating the role of exogenous variables in explaining inefficiency effects adopted a two-stage formulation, which suffered from a serious econometric problem.

Later, Battese and Coelli (1995) formulated a stochastic frontier production model, similar to that of Huang and Liu (1994), specified for panel data. The simultaneous estimation approach has a major advantage over the first approach in that it is based on a two-step procedure for examining the role of exogenous variables in explaining the *TE* of production.

A number of studies have been carried out using this approach to estimate *TE* and to determine factors which influence the efficiency of farmers, especially in the agricultural sector (Onumah and Acquah, 2010; Villano *et al.,* 2010; Nasiri and Singh, 2010; Kumbhakar *et al.,* 2011; Oyewo, 2011; Edeh and Awoke, 2011).

Given its superiority, this study adopts the Battese and Coelli (1995) model with some modifications to fit with cross sectional data. The model consists of two equations. The first equation specifies the stochastic frontier production function. The second equation, which captures the effects of technical inefficiency, has a systematic component, $\delta' z_i$, associated with the exogenous variables and a random component, ε_i :

$$LnY_i = Lnf(X_i;\beta) + v_i - u_i \quad (1)$$

$$u_i = \delta' z_i + \varepsilon_i \quad (2)$$

Where, Y_i denotes the output quantity for the i^{th} farm; X_i is a (k×k) matrix of quantities of known functions of inputs of production of the i^{th} farm; and β is a (k×1) vector of unknown parameters to be estimated.

The random variable, ε_i, is defined by the truncation of the normal distribution with zero mean and variation, σ^2, such that the point of truncation is $-\delta' z_i$, i.e., $\varepsilon_i \geq -\delta' z_i$. These assumptions are consistent with u_i being a non-negative truncation of the normal distribution, $N(\delta' z_i, \sigma^2)$.

The inefficiency frontier production function (1)–(2) differs from that of Reifschneider and Stevenson (1991) and the ε-random variables are neither identically distributed nor are they required to be non-negative (Battese and Coelli, 1995). Further, the mean, δz_i, of the normal distribution, which is truncated at zero to obtain the distribution of u_i is not required to be positive for each observation, as in Reifschneider and Stevenson (1991).

The assumption that the u_is and the v_is are independently distributed for all *i=1, 2,..., N*, is obviously a simplifying, but restrictive, condition. The non-negativity condition on u_i is modeled as $\varepsilon_i \sim N(0, \sigma_\varepsilon^2)$, with the distribution of ε_i being bounded below by the truncation point $-\delta' z_i$ and v_i are random errors assumed to be independent (of u_i) and identically distributed $N(0, \sigma_v^2)$. Then, it follows that the *TE* of production for the i^{th} farm can be defined as follows:

$$TE_i = \exp(-u_i) = \exp(-\delta' z_i - \varepsilon_i)$$

$$= \exp\left[-E\left(u_i / w_i\right)\right] = 1 - E\left(u_i / w_i\right) \quad (3)$$

Thus, the *TE* of a farmer is between zero and one and is inversely related to the inefficiency effect. The farm specific efficiencies are predicted using the predictor that is based on conditional expectation of U_i given composed error $W_i = (V_i - U_i)$. Farm specific or observation specific estimates of technical inefficiency, *U* (subscripts can safely be omitted here), can be obtained using the expectation of the inefficiency term conditional on the estimate of the entire composed error term, as suggested by Jondrow et al. (1982), and Kalirajan and Flinn (1983).

Prediction of *TE* is based on its conditional expectations, given the model's underlying assumptions. One can use either the expected value or the mode of this conditional distribution as an estimate of U:

$$E[U / w]=\sigma_{*}\left[\left(\frac{f(w\lambda/\sigma)}{1-F(w\lambda/\sigma)}\right)-\left(\frac{w\lambda}{\sigma}\right)\right] \quad (4)$$

Where, *f* and *F*, are the standard normal density and distribution functions, respectively, evaluated at:

$w\lambda/\sigma$, $\sigma_*^2=\frac{\sigma_v^2\,\sigma_u^2}{\sigma^2}$, $\lambda=\sigma_u/\sigma_v$ and

$\sigma^2=\sigma_u^2+\sigma_v^2$

The mean *TE* or the mathematical expectation of the farm-specific *TE* can be calculated for given distributional assumptions for the technical inefficiency effects. The mean *TE* can be defined as:

Mean TE= $E[\exp\{-E(U_i/w_i)\}]$ = $E[1-E(U_i/w_i)]$ (5)

The β and δ coefficients are unknown parameters to be estimated, together with the variance parameters, which are expressed in terms of:

$$\sigma_*^2=\frac{\sigma_v^2\,\sigma_u^2}{\sigma_v^2+\sigma_u^2} \quad (6)$$

$$\gamma=\frac{\sigma_u^2}{\sigma_v^2+\sigma_u^2} \quad (7)$$

Where, the γ-parameter has a value between zero and one. The parameters of the stochastic frontier production function in (1) and the model for technical inefficiency effects in (2) are simultaneously estimated by the maximum likelihood method, using version 4.1 of the *FRONTIER* computer program (Coelli, 1996).

Data Sources and Descriptive Analysis

The data used in this empirical application have been collected through two random sample surveys conducted in Jenin and Tubas Governorates of the West Bank of Palestine. These two townships cover a total land area of 985 km^2.

The selection of these two areas is justified by the fact that they are the most important field crops (wheat and barley) production zones with diverse farming systems in the West Bank (PCBS, 2008). Farmers in these districts are able to access basic agricultural services provided by governmental institutions. It is worth noting that NARC headquarters and the seed multiplication famers are located in Jenin.

The Governorate of Jenin (32° 27’ 43” N and 035° 18’ 05” E) is an important territory and covers an area of 583 square km. It has approximately 256,000 inhabitants that correspond to 11% of the total Palestinian population, with 42% in urban areas, 54% in rural and 4% living in refugee camps. It is one of the most important economic areas in the country. The agricultural sector in the Governorate of Jenin, with about 43,510 ha of arable land, currently represents 13.8% of the GDP, as compared to 8.2% of the rest of West Bank. The Jenin climate is hot and dry in summers and cool and rainy in winters, with average annual rainfall of 472 mm.

The Governorate of Tubas is located in the northeastern part of the West Bank (Latitude: 32°19′17″N and longitude: 35°22′09″ E). The total area of Tubas city is 295,123 dunums (1 dunum= 1000 m^2), which represents approximately 55.6 % of the Tubas Governorate's land area. Around 3,000 dunums are classified as 'built up' areas, whilst 150,000 dunums are agricultural, and 180,000 further dunums have been confiscated by Israeli occupation.

Tubas city's main source of livelihood is agriculture with 60% of the population working in various agricultural fields. The total area of arable land in the Tubas governorate is 150,000 dunums, whilst the cultivated area has reached 10,604 dunums. 124,450 further dunums are forests and 1,000 dunums are grazing area. Out of 10,604 dunums, 4,224 dunums are primarily under fruit trees, 1,160 dunums are cultivated with vegetables, and 5,215 dunums are cultivated with field crops. Tubas city is characterized by a moderate climate with hot and dry summers and cool winters. Rainfall is concentrated over the winter months, with mean precipitation in Tubas city of 329 mm, an average annual temperature of 21°C, and average annual humidity of 56%.

Primary data were obtained through farmer interviews using a structured questionnaire. A socioeconomic questionnaire was also used to collect information required to study characteristics of the communities within the geographical area of interest. Given that each community represented a unique agro-ecology, and a high degree of homogeneity among community members, as was evident from a Rapid Rural Appraisal and field visits, a simple random sampling approach was used to select a representative sample of 100 households within the two governorates (Jenin, 50 and Tubas, 50). Data covers information on infrastructure, marketing activities, equipment, crop production, extension, credit, water as well as household demographic characteristics. Information on crop farming activities included cost of seeds, land preparation, fertilizers and pesticides application, harvesting, et cetera. Information on wages and capital assets were also collected. The questionnaire was pre-tested, modified, and implemented within the two target sites.

Summary statistics of variables used in the empirical model, including mean, minimum and maximum values and standard deviations and the inefficiency variables are summarized in Table 1. Model variables indicated high variability among farmers being the case of the discrete variables of inefficiency model. This variation was justified considering the different levels of farms sizes and, consequently, the different levels of inputs used in the production process.

Farmers in both regions predominantly cultivate wheat. Table 1 describes selected characteristics of sample farms. Output is measured in monetary value (Israel Shekel) per dunum. The mean yield over the sampled farms was 672.92 ILS/dunum, with a range of 1,000 to 1,392 ILS/dunum. Land area was measured in terms of cropping area per farm, and within the agricultural season under which the survey was undertaken. Total land area in Table 1 is the sum of the total cropping areas under cultivation in the same cropping season. On average, land holding size is 39.41 dunum, ranging from 2 to 150 dunum. The input of

Table 1. Summary statistics of the variables used in the frontier model for rainfed agriculture farms in Jenin and Tubas (West Bank-Palestine).

Notation	Unit[a]	Mean	S.D	Minimum	Maximum
Total production value	ILS	26520.0	32385.45	2000	208700
Total cost value	ILS	18037.57	19297.18	630	161500
Farm size	Dunum	39.41	29.26	2	150
Cost of seeds	ILS	2210.5	1850.28	120	10200
Cost of fertilizers and pesticides	ILS	3604.5	3639.59	2400	29500
Cost of labor	ILS	2758.8	3216.15	1000	15090
Other costs	ILS	10028.5	16078.75	5100	157130
Age	Years	52.21	12.14	23	82
Farming experience	Years	27.45	12.40	5	60
Education level	Dummy variable	0.83	0.37	0	1
Family size	# of persons	6.94	2.57	1	14
Family labor/total labor	Percent	0.61	0.18	0.15	1
Off–farm income/total income	Percent	0.30	0.32	0	1
Extension services	Dummy variable	0.46	0.50	0	1
Training	Dummy variable	0.59	0.49	0	1
Access to credit	Dummy variable	0.30	0.46	0	1
Membership of cooperative	Dummy variable	0.61	0.49	0	1

[a] 1 ILS = USD 0.285 (average for 2011), 1 dunum= 1000 m^2. Source: Survey data, 2012.

total cost value was measured as the sum of cost of seeds, fertilizers and pesticides, labor, and costs of harvesting operations per farm. On average, harvesting operations constituted the highest costs followed by the costs of fertilizers and pesticides. In contrast, the cost of seeds was the lowest for the interviewed farmers. It is important to note that input costs as well as the output prices at the farm level did not vary substantially across the farms.

Farm and household characteristics variables utilized in the estimation of the TE model and its determinants included age, experience and education level of the household, off-farm income, extension services, training, and access to farm credit. Descriptive analysis of these variables indicated that the average age of respondents was 52 years, ranging from 23 to 82. Average farming experience of interviewers was 27.5 years, ranging from 5 to 60. It also appears that there are high levels of family labor with respect to total labor (61%) and, a low level of off-farm income with respect to total income (30%).

Empirical Stochastic Frontier Model

Cross-sectional data on 100 Palestinian farms in the Jenin and Tubas regions, covering the year 2011-2012, were used and a stochastic production frontier (SPF) function was specified as a function of inputs used. Functional form is an important consideration in the specification of an econometric model. Past studies on *TE* utilizing a stochastic frontier approach have used either Cobb-Douglas (CD) or the transcendental logarithmic (*translog*) functional forms. When second order and interaction terms in *translog* are restricted to zero, then the resulting functional form represents a Cobb-Douglas form.

In order to choose between Cobb-Douglas and translog frontier production functions, we employed a generalized likelihood-ratio (LR) test and the maximum likelihood (ML) estimates of the parameters of the functions were estimated. The results from this test revealed that the Cobb-Douglas form of stochastic frontier production function was more dependable than that of *translog* form under crop farming conditions in the West Bank of Palestine state. Thus, the Cobb-Douglas specification was found to be a better representation of the technology than the *translog* specification since the value of *LR*, 20.36, was greater than the critical value of the statistic χ^2_{11} (18.307) at 5% level of significance.

As indicated at the outset, data on output, production inputs (land, seeds, fertilizer, labor, and other costs related to the harvesting and collecting operations), and other explanatory variables were chosen for specifying the underlying Cobb-Douglas functional form.

Equations (8) and (9) below describe the stochastic frontier production model and the technical inefficiency-effects models, which will be simultaneously estimated.

$$LnY_i = \beta_0 + \beta_1 LnL_i + \beta_2 LnS_i + \beta_3 LnF_i + \beta_4 LnLA_i + \beta_5 LnOC_i + v_i - u_i \quad (8)$$

$$u_i = \delta_0 + \delta_1 (FEXP)_i + \delta_2 (EL)_i + \delta_3 (FLTL)_i + \delta_4 (IOF)_i + \delta_5 (EV)_i + \delta_6 (TR)_i + \delta_7 (CR)_i + \delta_8 (COP)_i + \varepsilon_i \quad (9)$$

Where, Y_i is the production value (ILS-Israel Shekel) of rain fed crops of the i^{th} farmer; L_i (+) is the area (*dunum*) cultivated by the i^{th} farmer; S_i (+) is the cost of seeds (ILS) used by the ith farmer; F_i (+) is the total cost (ILS) of fertilizers and pesticides used by the i^{th} farmer; LA_i (+) is total cost of labor (ILS) used by the i^{th} farmer; and OC_i (+) is the total cost (ILS) of other expenses (harvesting, collecting, etc.) used by the i^{th} farmer.

The variables used to explain the inefficiency are presented below. It is important to note that a negative sign of the estimated parameter indicates a positive relationship between TE and the variable under consideration. In contrast, a positive sign indicates a negative relationship. As expected, all the variables included in the inefficiency analysis are negative and, consequently, will affect the TE positively.

This indicates that farmer experience, their education level, the share of family labor of the total labor, their off-farm income, the availability of extension services, training and credit, and the membership in agricultural cooperatives tend to affect the degree of TE positively.

Variables employed, with expected signs in parentheses, were as follows:

FEXP (-): Years of farming experience;

EL (-): A dummy for farmer education level (1 if the farmer has accumulated at least 6 years of schooling, otherwise 0);

FLTL (-): The family's share of the total labor;

IOF (-): The proportion of the family's income earned off-farm (%);

EV (-): Perception of the extension services; a dummy variable (1 if the farmer is happy with extension services, otherwise 0);

TR (-): Training; a dummy variable, (1 if the farmer has participated in training, otherwise 0);

CR (-): Credit access; a dummy variable (1 if the farmer has the possibility of getting an agricultural loan, otherwise 0);

COP (-): Cooperative membership; a dummy variable, (1 if the farmer is a member of a cooperative, otherwise 0),

v_i and ε_i : Random errors.

RESULTS AND DISCUSSION

Cobb-Douglas Stochastic Frontier Model Estimates

Parameter estimates, together with standard errors and t-ratios of the *ML* estimators of the inefficiency frontier model of the West Bank farms are presented in Table 2. Signs on the estimated parameters of the Cobb-Douglas stochastic frontier production model are as expected. Among observed input productivity factors, harvesting and collecting operations and seeds productivity were the highest factors followed by fertilizers and land productivity. In addition, their estimated coefficients are

Table 2. Maximum likelihood estimates of the stochastic Cobb-Douglas production function.

Production factors	Parameter	Coefficient	Standard error	*t*-value[a]
Intercept	β_0	0.27	0.12	2.20**
Land (X_1)	β_1	0.21	0.10	2.08**
Seeds (X_2)	β_2	0.26	0.18	1.44*
Fertilizer (X_3)	β_3	0.22	0.14	1.51*
Labor (X_4)	β_4	0.07	0.07	1.09
Other costs (X_5)	β_5	0.35	0.18	1.90*
Return to scale *(RTS)*		**1.11**		
Inefficiency model				
Intercept	δ_0	-0.31	1.01	-0.31
Farmer experience (*FEXP*)	δ_1	0.55	0.54	1.02
Education level (*EL*)	δ_2	0.025	0.2	0.12
Family labor/total labor (*FLTL*)	δ_3	-0.48	0.53	-1.91*
Off-farm income (*IOF*)	δ_4	-0.10	0.23	-1.45*
Extension visit (*EV*)	δ_5	0.19	0.16	1.14
Training (*TR*)	δ_6	-0.17	0.19	-1.87*
Access to credit (*CR*)	δ_7	0.60	0.20	0.29
Membership of cooperative (*COP*)	δ_8	-0.72	0.166	-1.83*
Diagnostic statistics				
Log-likelihood function	LL		-11.52	
Total variance (σ^2)	σ^2	0.13	0.079	1.69*
Variance ratio (γ)	γ	0.82	0.14	5.64***
LR test	LR		18.74	
N		100		

[a] ***, **, * indicate statistical significance at 1.0, 5.0, and 10.0% respectively. Source: Model results.

positive and significant, which confirms the expected positive relationship between these inputs and crop production. Labor productivity was lower than the other inputs such as seeds, fertilizers, or harvesting inputs. These results may indicate that labor is not productive, and likely due to the high level of family labor used in the food crops production (61%). Jansouz et al. (2013) found similar results while examining the agriculture sector efficiency in Middle Eastern and North African (MENA) countries.

The estimate for the variance parameter, γ, is also significantly different from zero implying that the inefficiency effects are significant in determining the level and the variability of the West Bank crop producing farms. A γ value of 0.82 indicates that output oriented *TE* is important in explaining the total variability of the output produced. The remaining 0.18 i.e. the difference from 1, is a measure of the inefficiency arising from factors outside the control of the farmer (weather, diseases, etc.).

Estimates of production elasticities and returns to scale are also presented in Table 2. Estimated partial production elasticities with respect to these production factors indicate that other costs (mainly harvesting and collecting) and seed impact factors are greater than other intermediate factor inputs, such as fertilizers, land, and labor. The value of these elasticities are 0.21 for land, 0.26 for seeds, 0.22 for fertilizers (including pesticides), 0.07 for labor, and 0.35 for other costs. Hence, all things being equal, a percentage increase in all factors of production will result in 1.11 percent increase in output. The estimated return to scale is similar to the 1.26 estimated by Abugamea (2008) for the Palestinian agriculture sector during the period 2003-2008.

These elasticities suggest that a percentage change in the cost of seeds, cost of harvesting and cost of fertilizers would have a large positive effect on production value while only a modest positive effect on demand for labor. These results reflect the economic reality of crop producing farms in the region, where agriculture productivity growth in the West Bank is intermediate-input using, capital saving, and labor neutral (not significant where it appears with a minimal effect on the production due to the high share of family labor as explained previously). These results are in line with the findings reported by Dhehibi et al. (2012) for Tunisian wheat producing farms.

Cereals are the main crop produced and their cultivation is principally associated with harvesting and seed costs. The labor input factor has a minimal effect on production since all of the operations in cereal producing farms are mechanized or use family labor, which represents more than 60%, on average, of the total labor. In economic terms, the latter means that holding all other inputs constant, a percent reduction/increase in labor leads to a sacrifice/increase of 0.07% in the output. In contrast, the hypothesis of constant returns to scale is rejected at the 5% level of significance and returns to scale were found to be increasing (1.11).

Determinants of Technical Efficiency

Estimated coefficients in the technical inefficiency model are presented in Table 2. The estimated coefficient for the proportion of family labor in the total labor is negative and statistically significant at the 10% level, which indicates their positive effect on *TE*. Thus, the share of family labor of the total labor variable tends to affect the degree of *TE* positively. This positive relationship is often attributed to imperfect labor markets in West Bank i.e. lack of off-farm employment opportunities (Verma and Bromley, 1987).

With respect to off-farm income, a variable, which is of particular interest to policy makers, it is significantly (at the 10% level) negative. This negative coefficient suggests that off-farm income improves the farm *TE* since it contributes to farmer's adoption of new technologies and practices by easing farmers' liquidity constraints, which implies spill over effect's spread of the off-farm income on farm *TE.*

The training variable coefficient is found to be negative and significant at 10% level suggesting that an increase in the training programs for farmers could contribute to higher *TE* levels of crop production on these farms. This is consistent with literature on the role of education in technology adoption. Schooling has been shown to provide substantial externality benefits by increasing farm output and shifting the production frontier outwards. More educated farmers accompanied with an efficient extension services are more likely to adopt technologies earlier (Weir and Knight, 2005).

The coefficient of the membership of the farmer in a cooperative is negative and significant at the 10% level indicating a positive relationship with *TE.* This suggests that farmers should be organized in cooperatives, given the relative efficiency of such organizations in contrast to other weak associations available (marketing associations and farmers' unions) in the region (Personal communication, November 6, 2012).

Based on the model discussed in the previous section, a further analysis was carried out with special emphasis on the main determinants of *TE.* A partial comparison based only on *TE* scores between Jenin and Tubas farms indicated that farmers in Jenin were relatively more efficient than farmers in Tubas. The computed average *TE* in Jenin was 78%, ranging from a minimum of 35% to a maximum of 95%. This implied that Jenin farmers were producing on average at 78% of their potential and these farmers could increase their production by 22% by more optimal use of inputs. Tubas farmers were considered less efficient relative to Jenin, since the computed average *TE* was 65% and they could increase their production, using the same level of inputs, by about 35% (Table 3).

This can be explained by rainfall in Tubas ranging between 200 and 450 mm year^{-1}. In contrast, in Jenin, the rainfall ranges between 350 and 600 mm year^{-1}. In addition, the poverty rate in Jenin is more than that in Tubas –as documented by several international organizations– with more people working in agriculture than is the case in Jenin (Applied Research Institute–Jerusalem, 2006). Finally, most of the Tubas area is in the Jordan Valley (low rainfall), or close to it, and restrictions on planting land are imposed by the Israeli government.

Estimated Technical Efficiency Scores

Table 4 shows frequency distribution of farms specific technical efficiency estimates for West Bank farms from Cobb-Douglas stochastic frontiers. The results reveal great variability between farms (Table 4).

Estimated efficiency measures in Table 4 reveal the existence of substantial technical inefficiencies of production in the sample of crop producing farms at hand. The computed average *TE* is 72.2%, ranging from 35.7 to 95.6%. This implies that, given the present state of technology and input levels, farms in the sample are producing, on average, 72% of their potential, and these farms can increase their production by 28% simply by more optimal use of current input levels and within the current state of technology.

Table 3. Descriptive statistics of farm level TE according to farm location.

Technical efficiency	Mean (%)	Standard deviation	Minimum	Maximum
TE (Jenin)	78	0.11	0.35	0.95
TE (Tubas)	65	0.15	0.36	0.93
TE (Total pooled sample of farms)	72	0.14	0.35	0.95

Source: model results.

Table 4. Frequency distribution of *TE.*

Efficiency (%)	*TE*	
	No.[(a)]	Percentage[(b)]
0.0 – 0.1	0	0
0.1 – 0.2	0	0
0.2 – 0.3	0	0
0.3 – 0.4	3	3
0.4 – 0.5	7	7
0.5 – 0.6	12	12
0.6 – 0.7	18	18
0.7 – 0.8	23	23
0.8 – 0.9	29	29
0.9 - 1	8	8
Mean (%)	72.2	
Minimum (%)	35.7	
Maximum (%)	95.6	

[a] The number of farms, [b] The percentage (rounded) of total farms.
Source: Model results.

Within this framework, 60 farms are relatively more efficient than the sample average efficiency level, with an efficiency score greater than 70%, while 40 farms show a mean efficiency less than the average. These results raise questions about heterogeneity and a possibility that these farms can increase their production by 30% with the present state of technology and inputs level. Thus, it is questionable whether West Bank farmers are fully exploiting their resources in order to achieve higher yields.

One way of approaching the relationship between TE and yield gap is through the estimation and explanation of farm inefficiencies that are directly related to crop yields gap, since the crop yield, a partial measure of farm productivity, is related to the concept of TE as follows (Duwayri *et al.,* 2000):

Potential rain fed crop yield= Actual rain fed crop yield/TE

Rain fed crop yield loss= Potential rain fed crop yield–Actual rain fed crop yield.

Empirical results presented in Table 5 indicate that there is a negative relationship between *TE* level and loss of yield. As the *TE* of farmers increase, potential yield losses will gradually become smaller. Farmers who have achieved between 40% and 60% TE have lost about 48% of their potential yield because of their inefficiency. In contrast, farmers who have achieved between 80 and 100% TE have lost only 13% of their potential yield. These findings indicate that even though the crop yield level is high for these farms, there still exists a gap between what is achieved and what could be achieved in yield among the farmers, thereby questioning how efficiently the farmers are using their resources. Since resource use is inefficient, production can be increased by

Table 5. Mean *TE*, actual and potential yields, and potential yield loss by *TE* groups.

TE range (%)	Mean *TE* (%)	Number of farms	Mean of actual rainfed crop yield (ILS dunum^{-1})	Mean of potential rainfed crop yield (ILS dunum^{-1})	Potential rainfed crop yield loss ((ILS dunum^{-1})	Rainfed crop yield loss (%)
0 – 40	37	3	87.46	235.74	148.28	62.89
40 – 60	51	19	278.56	538.036	259.47	48.22
60 – 80	71	41	1793.13	2516.97	723.84	28.75
80 - 100	86	37	3143.03	3626.31	483.27	13.32

Source: Model results.

making adjustments in the use of factors of production in the optimal direction.

Finally, a further analysis was undertaken to assess the correlation between the *TE* and the input used. Relevant findings are presented in Table 6.

It appears that there are differences in the costs of inputs used for production in the study area (Table 6). However, the most technically efficient farms use more inputs than those farmers who are technically less efficient (with the exception of seed and fertilizers for the farmers who have achieved between 0 and 40% TE). According to the information collected during the implementation of the surveys, a majority of farmers in the West Bank obtain their seed from informal sources; hence, they prefer selecting their seed from previous harvest instead of buying certified seed. This is one possible explanation for the inverse relationship between seed and *TE.* Some authors such as Singh et al. (2009) have reported that seed quality is an important determinant of *TE.* Seed positively and significantly affects the *TE* of commercial wheat farms in Ethiopia (Kebede and Adenew, 2011).

Farmers who achieved between 40 and 60% *TE* used "other" inputs, such us mechanization (expressed in monetary terms), more than the other farmers. Analysis of the data indicates that those farmers who used more 'other' inputs such as mechanization did not apply them appropriately, hence increasing the level of usage of 'other' inputs may not only result in low farm productivity, it may even be hazardous to the farmer.

CONCLUSIONS

A Cobb-Douglas production frontier function was utilized in this study to examine *TE* and its determinants of crops production in the West Bank. Estimates showed that the mean levels of *TE* were relatively low, but there were significant variations in efficiency scores of different farms.

Empirical findings suggest that the more technically efficient the farmers become, the less will be the potential yield loss. Farmers who have achieved between 40 and 60% TE have lost about 48% of their potential yield due to their inefficient use of inputs. However, farmers who have achieved between 80 and 100% *TE* have lost only 13% of their potential yield due to inefficiency.

The estimated coefficients of *TE* of the farms in the studied sample ranged between 35.7 to 95.6%, with a mean value of 72.2%. This suggests that, on average, the interviewed farmers can potentially increase their production by as much as 28% through more efficient use of production inputs. This result implies that there is considerable scope to improve crop production in the study region. Further, considering the high cost of inputs and their limited availability, the potential for increasing production by using more traditional inputs is limited.

Indeed, *TE* increases when the share of family labor with respect to total labor is high. In addition, the higher levels of training and education offer effective ways of increasing efficiency and a strong

Table 6. *TE* and inputs used.

TE range (%)	Mean *TE* (%)	Number of farms	Mean cropped land (dunum)	Mean seeds (ILS dunum^{-1})	Mean fertilizers (ILS dunum^{-1})	Mean labour (ILS dunum^{-1})	Mean other costs ((ILS dunum^{-1})
0 – 40	37	3	51.66	2,466.66	6,066.66	1,832.7	8,516.66
40 – 60	51	19	34.63	1,644.47	2,883.92	2,219.07	15,047.63
60 – 80	71	41	42.60	2,382.31	3,510.59	2,462.23	8,735.07
80 - 100	86	37	37.32	2,290	3,879.01	3,439.83	9,006.89

Source: Model results.

correlation was observed between these variables and *TE*. This highlights the need for government policies to set up training programs through extension activities on crop production (rotation, time of sowing, etc.), in general, and improve management –a combination of production factors – in particular.

Furthermore, a positive and significant association between farm *TE* and off-farm income confirms that off-farm income improves the farm *TE*, which implies spillover effects of off-farm income on farm *TE*. On one hand, off-farm income provides cash flow into a farm, which can be also invested into farm technological advancements to improve farm *TE*. On the other hand, the off-farm employment, which is associated with the off-farm incomes, relaxes possible farm labor surpluses outside the main seasonal work. This, in turn, gives the farm an opportunity to maximize farm output, at a given technology, and through less off farm labor employment.

Moreover, farmers who are members of a cooperative reach a higher level of *TE* as compared with farmers who are not members. This implies that not only the creation of such organizations should be encouraged, but also that farmers should be encouraged to take up memberships in them.

Finally, access to credit positively affects *TE*. The policy implications that can be drawn from this result includes the need for a review of agricultural loan policies from government banks, private banks, and microfinance institutions (MFIs) in order to provide better and wider access to credit for Palestinian farmers in the West Bank.

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کارآیی فنی و عامل های موثر بر آن در تولید گیاهان خوراکی: مطالعه موردی در مزارع کرانه غربی فلسطین

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چکیده

در این پژوهش، کارآیی فنی در سطح مزرعه(TE) و عامل های موثر بر آن بررسی شد. به این منظور، برای برآورد کارآیی فنی مبتنی برنهاده، ازمدل تولید احتمالی (استوکاستیک) کاب–داگلاس در ۱۰۰ مزرعه دیمکاری نمونه انتخاب شده واقع در دو فرمانداری فلسطینی (جنین و توباس) استفاده شد. یافته های تجربی نشان داد که برآوردهای کار آیی فنی در مزارع مورد مطالعه بین ۳۵/۷ ٪ و ۹۵/۶٪ و میانگین آنها برابر ۷۲/۲٪ بود. بر این اساس، به طور میانگین، مزارع واقع در جنین و توباس مستعدا می توانند از طریق کار آیی بیشتر در مصرف نهاده ها، بهره وری خود را تا ۲۸٪ افزایش دهند. تجزیه و تحلیل عامل های موثر بر کارآیی فنی چنین اشاره داشتند که رابطه ای مثبت بین عضویت در تعاونی با سطح تحصیلات، تجربه، دسترسی به اعتبارات مالی و خدمات ترویجی وجود دارد. نظر ما این است که دسترسی به اعتبارات مالی و تقویت ظرفیت خدمات ترویجی ملی، عرصه های مهمی در زمینه سیاست های عمومی برای اثر گذاری بر سطح تولید و بهره وری کشاورزی در کرانه غربی هستند.