Pakistan Journal of Applied Economics, Vol.31 No.2, (191-208), Winter 2021

AN ANALYSIS OF AGRICULTURAL PRODUCTION IN PAKISTAN: A Study Based on the Asymmetric Role of Inputs

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Abstract

Agricultural inputs are peculiar in nature as an asymmetry in their roles can be identified during the production process. These inputs can be grouped into a set of growth inputs or a set of facilitating inputs. The inputs affecting biological or physiological growth from the inside of the plant are called growth inputs, e.g., water, nutrients, seed and soil. The inputs that affect plant growth indirectly, such that they regulate the role of growth inputs from outer environments of plants, e.g., pesticides, capital, and labour, are facilitating inputs. This concept of asymmetry, based upon agronomic principles of crop production, is incorporated in agricultural economics by Zhengfei, Oude Lansink, van Ittersum, and Wossink (2006). This variant role of inputs is studied by using farm household-level data. In Pakistan, this study is one of the first studies that employ a double bootstrap methodology for two-stage analysis in a semiparametric way. It is reported that pesticides, family labour, and capital enhance the Technical Efficiency (TE) of growth inputs. However, hired labour affects negatively. The study also shows the effect of farm size on productivity.

Keywords: Data Envelopment Analysis, Technical Efficiency, Double Bootstrap Procedure, Damage Control, Growth Inputs, Facilitating Inputs, Farm Size-Productivity.
JEL Classification: C1, C44, C61, D13, D24, Q12.

I. Introduction

There is a primary difference between the agricultural production process and other processes of production. The former is subjected to various natural factors which cannot be controlled directly by farmers. The inputs used for agricultural production have an asymmetry in their roles played during the process of production. Many agricultural economists elaborate a distinction in the roles of inputs. An asymmetric role of inputs means that agricultural inputs contribute in a different direction in the pro-

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duction process. Lichtenberg and Zilberman (1986) argue that pesticides are different from other inputs with respect to their role. Pesticides do not help in increasing the production of any crop. However, they help in minimising the damage caused by various damaging agents. If there is no pest infestation or no danger of pest attack, the application of pesticides will result in no extra gain in the harvest. Such types of inputs which are responsible for minimising the damage caused by the biological factors are termed as Damage Control Inputs; the econometric procedure which analyses this asymmetry is called Damage Control Econometrics. Lichtenberg and Zilberman (1986) explain that agricultural inputs are either direct inputs or damage control inputs. A usual model specification that involves damage control inputs along with direct inputs (i.e., symmetric way) results in biased estimates for the marginal productivities of the formal ones, i.e., the inputs intended to control the damage. The usual form of agricultural production function can be shown as:

$$Q = f(X) \tag{1}$$

In this Equation (1), Q represents output, whereas X indicates the vector of different inputs. The above functional form is symmetric, i.e., it assumes that all the inputs are responsible for increasing the output. In general, this specification is employed usually in Cobb-Douglas settings. In Pakistan, various studies proposed an alternate production like Bakhsh, et al., (2004), Hassan, et al., (2005) and Lichtenberg and Zilberman (1986).

$$Q = f[x, G(z)] \tag{2}$$

Again Q is output, x a vector of direct inputs in the above Equation (2). The second part of the above function is a scaling function represented by G that assumes values in an interval [0, 1], and z represents a vector in which both Damage Control Inputs and Damaging Agents are included. If $G = 1$, then the actual yield equals potential yield that is no loss by the pests, whereas if $G = 0$, it means no output (i.e., complete loss of the output). This functional specification assumes separability between different inputs. Separability may be defined as the Marginal Rate of Technical Substitution (MRTS) among inputs that belong to one group, is not affected by any combination among the inputs contained in a different group. The popularity of damage control econometrics was immediately highlighted in the agricultural economics literature [Babcock et al., (1992), Blackwell and Pagoulatos (1992), Carrasco-Tauber and Moffitt (1992) Fox and Weersink (1995) and Harper and Zilberman (1989)].

Among the various forms of damage control function given in the literature, the famous ones are exponential, Weibull, logistic, Pareto, etc. It is acknowledged that asymmetry in the role of inputs should be considered while modelling the agricultural production function. However, the use of different functional forms have resulted in different and sometimes opposite estimates for Damage Control Inputs. Some forms mention high, the others show low, and some even negative estimates of pesticides. Therefore, the consensus has yet to come on which functional specification should be used, particularly for the Damage Control Function.

The limitation of the parametric analysis is that a priory functional form has to be assumed; because of this problem functional specification, some researchers, e.g., Kuosmanen, et al. (2006), have proposed a semi-parametric methodology of analysis of the agricultural production process. This approach combines the strengths of both parametric and non-parametric analysis. The semi-parametric methodology employs a two-stage analysis. In the first stage Data Envelopment Analysis (DEA) is used to calculate the Technical Efficiency (TE), and in the second stage analysis Tobit regression is used.

The analytical framework of the above mentioned Kuosmanen, et al., (2006) was based upon the concept of separability between damage control inputs and direct inputs. Zhengfei, et al., (2006) contend that this separability covers a larger sense in the process of agricultural production. Agricultural inputs may be divided into growth inputs and facilitating inputs. The growth inputs induce the biological growth and development of plants. They affect the plant growth from the inner or physiological environment of the plants, for example, water, nutrients, seed, and soil environment. Whereas facilitating inputs are those that affect the plant growth from the outer environment of the plant, for example, labour, capital, and pesticides. In other words, the efficiency of growth inputs is affected by the facilitating inputs. The facilitating inputs act as the scaling factors, i.e., they minimise the gap between actual output and potential output. However, the analysis done by Zhengfei, et al., (2006) was based upon a parametric translog function.

Kuosmanen, et al., (2006) prefer the non-parametric methods because no functional form is assumed a priory in these methods. They argued that analysis done non-parametrically produces equally comparable results even under the best conditions of parametric analysis. Initially, the non-parametric techniques lack statistical properties. However, present-day thank semi-parametric techniques of econometrics that this weakness is over [Simar and Wilson (2007)].

This is a semi-parametric study based on the concept of the dichotomy of inputs with a particular emphasis on pesticides and labour. Earlier Zhengfei et al., (2006) have explained how the inputs used in agriculture are separable and they used a parametric translog functional form of the production function for this demonstration. The prime objective of this study is to extend the analysis presented by Zhengfei, et al., (2006) and demonstrate that how semi-parametric techniques may be employed for the purpose. Simar and Wilson (2007) highlight certain weaknesses in a traditional two-stage methodology. Technical efficiency (TE) scores calculated with DEA are usually upward biased. The sample may not include some possible Decision-Making Units (DMUs), which are more efficient than the DMUs included in the sample. Secondly, the TE of any DMU is dependent upon the input-output combination of its own but also on the other DMUs. So the resultant error term in the second stage regression is correlated with each other hence not independent. Thirdly, many variables, i.e., used in the calculation of TE scores, are not included in the second stage regression so, they may be correlated with the error term. Lastly, The TE scores are bounded [0, 1]. Most of the studies that employ a two-stage analysis use Tobit regression because of this bounded nature of TE but ignore the first three issues. To overcome these problems, Simar and Wilson (2007) proposed a two-stage semi-parametric double Bootstrap Procedure that can solve these econometric issues. This methodology is relatively complicated, but it produces robust results. Many researchers have used this methodology, like Balcombe, et al., (2008) Barros and Dieke (2008), Blank and Valdmanis (2010) and Latruffe, et al., (2008). This study also uses this methodology and therefore is one of the first studies in Pakistan that have employed this procedure.

The present study is divided into different sections. Section II covers the conceptual framework. Section III discusses the econometric procedure; Section IV shows results and discussion. Lastly, Section V contains concluding remarks and policy implications.

II. Conceptual Framework

Natural factors such as climatic conditions and biological factors such as the prevalence of pests cannot be controlled at the farmer's level; this is the condition that distinguishes industrial and agricultural production processes. In normal field conditions, these factors are taken as given and the farmers have to adapt their practices accordingly. Moreover, there is an asymmetry in the roles of agricultural inputs. Zhengfei, et al., (2006) categorised these inputs into two groups, i.e. Facilitating Inputs and Growth Inputs. Capital, labour, and pesticides are included in the first group, whereas; water, seed, soil environment, and nutrients are included in the second group of inputs. This grouping of the inputs is based upon the agronomic principles followed in crop farming. Separability as a concept of the model specification for production function analysis was presented by Lichtenberg and Zilberman (1986). The separable production function in general form may be written as $Q = f[z,g(x)]$. Here Q represents farm output. Direct inputs given as z and x are vector forms of damage control and state variables, respectively. The production function is given as $f(.)$ and $g(.)$ is a function for damage abatement. The $g(.)$ denotes a scaling function whose values are bounded in [0, 1] interval. When the value of $g(.)$ equals (1) it means actual output equals the potential output whereas this function's (0) value means complete loss of output. When $g(0)$ then $Q = f[z,0]$ and when $g(1)$ then $Q = f[z,1]$.

Kuosmanen, et al., (2006) argued a multiplicative separability in the above-mentioned functions in which production and damage control functions are imbedded into one function.

Where explanations of *f* and *g* are same as given above; if the inputs in one group do not vary with the change in the combination of inputs that belong to another group, these two groups of inputs are separable. This can be expressed mathematically in Equation (3) and (4):

$$\frac{\partial}{\partial z_k}\left(\frac{\partial q/\partial x_i}{\partial q/\partial x_j}\right) = 0 \qquad \forall i, j, k, \text{ and } i \neq j \tag{3}$$

and

$$\frac{\partial}{\partial x_k}\left(\frac{\partial q/\partial z_i}{\partial q/\partial z_j}\right) = 0 \qquad \forall i, j, k, \text{ and } i \neq j \tag{4}$$

The above Equation (1) can be modified in Equation (5) given below:

$$g(y, z) = \frac{q}{f(x)} \tag{5}$$

The right-hand side expression of Equation (5) is the inverse of output-oriented Technical Efficiency (TE). Both Parametric techniques, stochastic frontier analysis (SFA) and non-parametric Data Envelopment Analysis (DEA) methods are used to measure technical efficiency. While studying other parametric methods, Jankowski, et al., (2007) mentioned that different researchers choose various functional forms to capture the role of damage control inputs; however, there is a lack of consensus so far. The agricultural economists, Lansink and Silva (2004) preferred non-parametric ways to analyse separability. The proposed separability among the inputs by Zhengfei, et al. (2006) can be given as in alteration of the Equation (1) in the following expression:

$$q = f(x_1, x_2, x_3)\ .g\ (z_1, z_2, z_3, z_4)$$

or

$$g\ (z_1, z_2, z_3, z_4) = \frac{q}{f(x_1, x_2, x_3)} \tag{6}$$

Both sides of the above Equation (6) are unknown that be estimated parametrically and non-parametrically. Charnes, et al., (1978) proposed a non-parametric Data Envelopment Analysis (DEA), which can be used to estimate the right-hand side part of the Equation. However, Truncated Regression that in parametric form may be used for the left-hand side of the Equation. Therefore, it turns out to be a two-stage analysis. To address the issues in the traditional two-stage analysis, Simar and Wilson (2007) proposed a double bootstrap procedure which can be employed in the present stage.

III. Econometric Procedure

DEA method is given as under which is a technique based upon linear programming.

$$\max \theta = (\sum_{r=1}^{s} u_r q_r)_0 \qquad (7)$$

Subject to

$$(\sum_{i=1}^{m} v_m x_m)_0 = 1$$

$$\sum_{r=1}^{s} (u_r q_r)_j \leq \sum_{i=1}^{m} (v_i x_i)_j$$

$$u_r, v_i \geq 0$$

This constant returns to scale, the output-oriented model is run for each farm separately. In the first stage, DEA is employed to get TE scores for each farm. These TE scores are regressed on a set of variables included in the facilitating inputs. This analysis was carried out under Double Bootstrap Procedure.

1. Data

Agricultural sheet data from Pakistan Social and Living Standards Measurement Survey (PSLM) 2007-08 were used for this investigation. Ten irrigated districts from central Punjab were purposively selected. These districts were then divided into four regions on the basis of similarities in the cropping pattern. The districts, along with respective ID codes and Regions, are given in Table 1 below.

TABLE 1

Districts Included in Analysis

Sr. No	Name of Districts	Identity Code (ID)	Region Assigned
1.	Sargodha	6	1
2.	Faisalabad	10	1
3.	Toba Tek Singh	11	2
4.	Jhang	12	2
5.	Gujranwala	13	3
6.	Hafizabad	16	3
7.	Sheikhupura	22	3
8.	Okara	21	4
9.	Sahiwal	24	4
10.	Pakpattan	27	4

Source: (ID) Codes of districts are according to the coding scheme of PSLM; regions are assigned ID 1-4 by the authors and are based on cropping patterns. In the coming analysis, the Regions are expressed as r1, r2, r3 and r4.

2. *Description about Cropping Pattern*

Among many others, five major crops grown in the Province of Punjab are Wheat, Rice, Maize, Cotton and Sugarcane. Detail about the crop area for major crops is provided in Table 2 below. In the districts included in the present analysis, these crops constitute nearly 80 per cent of the total cropped area. Wheat is grown in these districts and covers about 40 per cent of cropped areas in all the districts.

TABLE 2

District-wise Area under Major Crops

Districts	Area under crops (Acres)					
	Total Cropped Area	Wheat	Rice	Maize	Cotton	Sugarcane
Sargodha	2129055	745169.3	298067.7	21290.55	42581.1	149033.9
Faisalabad	1698286	747245.8	186811.5	16982.86	84914.3	271725.8
TobaTek Singh	873824	375744.3	104858.9	26214.72	122335.4	69905.92
Jhang	1606615	674778.3	321323	-	160661.5	96396.9
Gujranwala	1446838	636608.7	636608.7	-	-	-
Hafizabad	791604	340389.7	340389.7	-	-	-
Sheikhupura	766832	352742.7	337406.1	-	-	-
Sahiwal	1111905	422523.9	144547.7	77833.35	211262	11119.05
Okara	1556362	591417.6	357963.3	108945.3	124509	31127.24
Pakpattan	1136749	409229.6	261452.3	79572.43	136409.9	11367.49
Districts	**Area under crops (per cent of total cropped area)**					
	Total Cropped Area	**Wheat**	**Rice**	**Maize**	**Cotton**	**Sugarcane**
Sargodha	2129055	35	14	1	2	7
Faisalabad	1698286	44	11	1	5	16
TobaTek Singh	873824	43	12	3	14	8
Jhang	1606615	42	20	-	10	6
Gujranwala	1446838	44	44	-	-	-
Hafizabad	791604	43	43	-	-	-
Sheikhupura	766832	46	44	-	-	-
Sahiwal	1111905	38	13	7	19	1
Okara	1556362	38	23	7	8	2
Pakpattan	1136749	36	23	7	12	1

Source: Authors' estimation based upon GoP (2010) '-'mean area less than 0.5 percent.

In Region-1, Sugarcane is the important crop besides wheat, covering 11 per cent of the total cropped area. Almost no Sugarcane is grown in Region-3 and it constitutes 6.7 per cent and 1.4 per cent of cropped area in Regions-2 and Region-4, respectively. Similarly, Cotton is the dominant crop in Region-4 after Wheat that covers more than 12 per cent of the total cropped area of this Region. Moreover, this region also has the largest cropped area under maise crop as a per cent of the total cropped area, i.e. 7 per cent. The coverage of Cotton and maise crops with respect to the area is less in all other regions as compared to Region-4.

Rice crop dominates in Region-3 after Wheat, where it captures about 44 per cent of the cropped area. Although Rice is grown in other regions, it covers a lesser percentage of the total cropped area. There is a mixed pattern that can be observed in Region-2. Although all the major crops are grown there, they share a lesser percentage of the total crop area compared to other regions.

TABLE 3

Description of Variables

Variable	Inputs Category	Variables Definitions	Mean	SD	Min	Max
Q		TOTAL PRODUCTION [per acre (000 Rs)]	32.86	23.98	4.56	344.2
X_1	GI	TOTAL FARMLAND IN OPERATION (acres)	7.75	7.92	0.38	50
X_2	GI	SEED COST [per acre (000 Rs)]	1.72	1.85	0.04	15
X_3	GI	FERTILIZER COST [per acre (000 Rs)]	3.47	2.88	0.18	28.5
X_4	GI	IRRIGATION COST [per acre (000 Rs)]	3.22	4.21	0.05	42.34
Z_1	FI	PESTICIDES COST [per acre (000 Rs)]	1.85	2.17	0.02	13.11
Z_2	FI	RENT ON CAPITAL [per acre (000 Rs)]	2.46	1.99	0.08	22
Z_3	FI	MONTHLY FAMILY WORKERS DAYS IN AN HH	9.08	8.23	0	73.68
Z_4	FI	PERMANENT AND CASUAL HIRED LABOR COST [per acre (000 Rs)]	3.5	3.91	0.04	30

Source: Authors' estimation.

Note: Conventionally X and Z are usually used for direct inputs and inputs as well as variables in the damage control function, respectively. The same convention is maintained in this study as well. GI is for Growth Inputs, FI is for Facilitating Inputs.

In this way, there are distinct four regions based on the cropping pattern. After Wheat crop, Sugarcane in Region-1, Rice in Region-3, Cotton and maise in Region-4 are the dominant crops. However, Region-2 is distinctly based on its mixed cropping pattern.

The dataset comprises three types of variables, i.e., one output, growth inputs, and facilitating inputs. The dataset Q is for output, X_1 to X_4 represent growth inputs, and Z_1 to Z_4 represent facilitating inputs. Table 3 describes these variables.

IV. Results and Discussion

As reported earlier, this is a two-stage semi-parametric analysis in which DEA in the first stage is used for Technical Efficiency (TE) of the growth inputs. The second stage comprises truncated regression of TE on the facilitating inputs. However, the double bootstrap procedure was adopted to get robust and bias-free results. Table 4 below and a subsequent Figure 1 show the DEA TE scores bias-corrected DEA score. It can be observed that bias-corrected mean TE scores are lower as compared to the biased TE score. The substantiates the argument that DEA TE scores are upward biased in usual settings.

TABLE 4

TE Scores and TE Scores (Bootstrapped)

District	Sargodha	Faisalabad	T.T. Singh	Jhang	Gujranwala	Hafizabad	Okara	Sheikhupura	Sahiwal	Pakpattan
TE Scores	0.526	0.563	0.54	0.391	0.459	0.781	0.613	0.506	0.32	0.589
TE Scores (Bias-corrected)	0.415	0.452	0.417	0.283	0.345	0.721	0.506	0.382	0.235	0.487

Source: Authors' estimation.

1. Facilitating Inputs Affecting the Technical Efficiency of Growth Inputs

The second stage comprises a truncated regression analysis. The present analysis is a sequel of previous research by Iqbal and Sial (2018) that studied the effects on TE due to the variables included in the group of facilitating inputs. The results indicated that facilitating inputs, pesticides, capital, and family labour is reported to have a positive impact on the efficiency of growth inputs. In contrast, hired labour has a negative effect. The positive effect of pesticides on productivity is also in line with Shafiq and Rehman (2000).

The use of pesticides in Pakistan is significantly cropped specific. More than half of the pesticides (60 per cent) are used on the Cotton crop only, followed by Rice and Sugar Cane [GOP (2010)]. The role of pesticides as facilitating inputs will be further explored

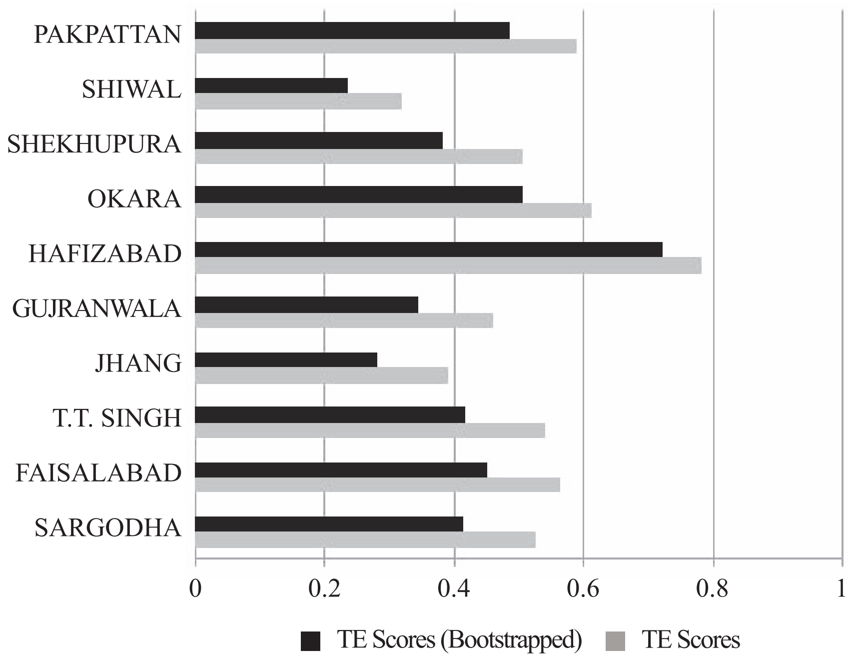

FIGURE 1

TE Scores and TE Scores (Bootstrapped)

in a separate section. Regions 2 and 4 are also statistically different from region1. Region 2 has higher productivity as compared to the base category of region 1. Whereas region 4 is lower in TE than region 1.

Capital in the form of agricultural machinery is highly productive and helps increase the TE of growth inputs. Pakistan is deficient in the capital so far; even the usage of farm mechanisation is on the rise in Pakistan. More use of machinery is associated with the increased Technical Efficiency of direct inputs used in agriculture. These results confirm the results reported in the studies [Bakhsh, et al., (2004) and Hassan, et al., (2005)]. Realising the situation, the use of machinery is increasing in private farms, as reported in [GOP (2010)].

The family members of the farm affect the technical efficacy of the farm positively by doing work. The effect of family workers on increasing productivity is positively significant in Pakistan [Ahmad (2003)]. In contrast, hired labour is not as productive as family labour engaged in agriculture and shows the signs of over employment in the sector. Shafiq and Rehman (2000) have also indicated the negative productivity of the hired labour. The issue of labour productivity in agriculture is also evident from the large-scale data and the number of farms operated by family workers increases over time [GOP (2010)]. There are also differences at the regional levels as captured by the regional dummies.

The pesticides used in agriculture demands a further detailed analysis because of increasing concerns about the environment. Moreover, as we have noticed, the hired labour negatively affects the efficiency of growth inputs. Therefore, we extend our analysis by studying the role of pesticides and hired labour in further detail.

2. Pesticides and Productivity

The Pesticides positively affect the technical efficiency of the direct inputs, but the marginal product is not the same across all the regions included in the analysis. Table 5 shows the results of the analysis. A quadratic type relationship has been observed in TE and pesticide use. The role of pesticides is the highest in region 1 and region 2 followed by region 4 and region 3, respectively. Since the t-value of the slope dummy for region 2 is not significant, it is concluded that the marginal product of pesticides for region 2 is not different from that of region 1.

The average use of pesticides by farms is low in all regions. Figure 2 shows that TE resulting from growth inputs can be increased by increasing the expenditure on pesticides. The first derivative is equal to zero; the amount of pesticide can be calculated to maximise the output holding the other inputs fixed at mean levels; this analysis is found in regions 1 and 2. The TE increases up to the expenditures of Rs: 8.84 thousand on pesticides per acre. Afterwards, the TE starts decreasing; whereas, in regions 3 and 4 the TE increases up to the expenditures of Rs: 5.4 thousand and 5.89 thousand respectively. Hence the scope of increase in expenditures on pesticides is higher in regions 1 and 2 as compared

TABLE 5

Pesticides and Productivity

Variable	Coefficients	SE	t-value
Intercept	0.8144 *	0.0132	61.586
Z_1 (Pesticide Cost)	0.0389 *	0.0096	4.064
Z_1^2 (Pesticide Cost Square)	-0.0022 **	0.0008	-2.698
Z_2 (Rent on Capital)	0.0144 *	0.0049	2.917
Z_3 (Family Labor Days)	0.0033 *	0.001	3.229
Z_4 (Hired Labor Cost)	-0.0054 **	0.0025	-2.199
$Z_1\_r_2$ (Slope dummy)	0.0289	0.0178	1.621
$Z_1\_r_3$ (Slope dummy)	-0.0149 **	0.0062	-2.399
$Z_1\_r_4$ (Slope dummy)	-0.0130 ***	0.0076	-1.696

Source: Authors' estimation.

Note: In this procedure, 100 and 2500 iterations were used in the first and second loop, respectively to get biased corrected DEA scores and robust estimates for the coefficients. * means 1%, ** means 5%, and *** indicates 10 % significance level.

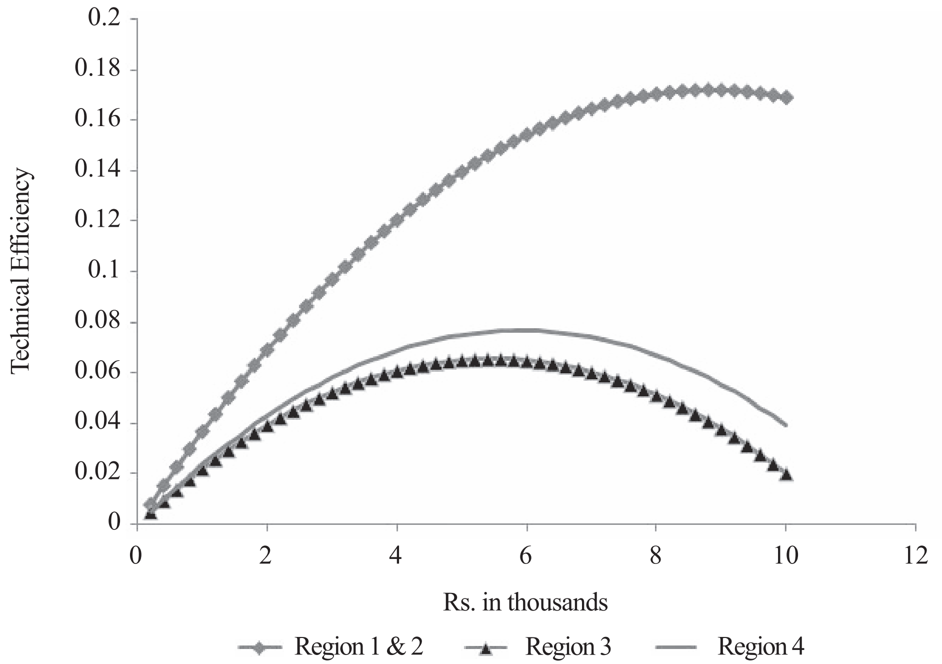

FIGURE 2

Pesticides and Productivity

to the other regions. The primary reason behind this strange result is that agriculture is more developed in regions 3 and 4 as compared to regions 1 and 2. Region 3 and 4 come in the rice and cotton zones. It is assumed that farmers in these regions use improved seed varieties like hybrid and BT varieties of the respective crop.

Genetically these varieties are resistant to insects and other diseases; consequently, there is lesser scope for increasing the use of pesticides. Huang, et al., (2002) also reported that the farmers who cultivated BT verities used lesser quantities of pesticides on their crops than the farmers who cultivated non-BT varieties. In other words, the increased use of pesticides helps increase farm productivity. Still, the maximum limit of the use of pesticides reaches early in regions 3 and 4 compared to regions 1 and 2. The values of the coefficients of all other variables have not changed much, and their signs are also stable.

3. Hired Labor and Productivity

The results indicate that any extra expenditure incurred on permanent and casually hired labour negatively affects TE of growth inputs. This time, the analysis reported in Table 6 is conducted by including regional slope dummies and keeping region 1 a reference category.

TABLE 6

Hired Labor and Productivity: Double Bootstrap Estimation

Variable	Coefficients	SE	t-value
Intercept	0.8158 *	0.0135	60.2684
Z_1(Pesticide Cost)	0.0174 *	0.0043	4.0259
Z_2 (Rent on Capital)	0.0182 *	0.0055	3.3141
Z_3 (Family Labor Days)	0.0035 *	0.0011	3.2362
Z_4 (Hired Labor Cost)	-0.0070 **	0.0031	-2.279
$Z_{4}\_r_2$ (Slope dummy)	0.0165 **	0.0063	2.6418
$Z_{4}\_r_3$ (Slope dummy)	0.0007	0.0031	0.238
$Z_{4}\_r_4$ (Slope dummy)	-0.0033	0.0028	-1.1917

Source: Authors' estimation.

Note: In this procedure, 100 and 2500 iterations were used in the first and second loop, respectively, to get biased corrected DEA scores and robust estimates for the coefficients. * is 1% and ** are 5% indicates significance level.

The values of slope dummies of regions 3 and 4 are not statistically different from region 1, whereas the value of region 2 is significant. The labour negatively affects TE of growth inputs in regions 1, 3 and 4 with a marginal value of -0.007. However, the contribution of hired labour is positive for TE of growth inputs in region 2 with a marginal value of (-0.007+0.0165 = 0.0095).

4. *Farm Size and Productivity*

Since the sixties, agricultural economists have shown interest in analysing farm size productivity relationships. This line of research started with the work of Sen (1962), where he found farm size and productivity move in the opposite way. Many later studies produced controversial results particularly focusing on labour and farm size ratios. Proponents of inverse productivity farm areas argue that smaller farms show higher productivity than large farms since small farms have more units of available family labour per unit of area. In contrast, the contending authors argue that with the advent of the Green Revolution, new inputs in the shape of fertilisers and farm machinery have reversed this relationship in favour of large farms by offsetting the inherent advantage of small farms in the shape of family labour [Fan and Chan-Kang (2005)]. In Pakistan, as well, the contributions by the economists in this area of research can be found [Sial, et al., (2012)]. However, these farm size and productivity relationships have never been studied in the context of the dichotomous role of agricultural inputs. Generally, linear or logarithmic specifications are used to study this type of relationship in the literature. However, it is assumed that this relationship is not so simple.

There may be some nonlinearity in this type of relationship because small farmers may not be able to use some of the inputs, e.g. some farm machinery, due to economic constraints. On the other hand, large farmers may face some management issues due to large farm areas. Therefore, it may be assumed that small farmers are inefficient because of financial constraints and large farmers are inefficient because of management constraints.

In Pakistan, there is found severe skewness in the landholdings. So, a linear form is not suitable for this type of analysis. Moreover, the logarithmic form can be suitable, but it cannot capture nonlinearity. Therefore, a log-quadratic form for farm area has been used in this analysis. Table 7 shows the results of the farm size-productivity relationship. The log-quadratic form is often used in studies of the Environmental Kuznets Curve [Agras and Chapman (1999)].

Log of farm size is significant at 10 per cent level, but the log-quadratic term seems insignificant on its face. However, in truncated regression in step 2 of the double bootstrap procedure, the joint significance was tested through the Wald Test. The null hypothesis was rejected with a p-value of 0.0171 and an F-statistic of 8.14.

The analysis shows that the TE of growth inputs increases as the farm size increase until it reaches 16 acres. After 16 acres, the TE starts declining. This time, regional dummies were omitted from the analysis because they were initially insignificant.

Following Dowling (1980), setting the first derivative equal to zero, farm size where TE is maximised can be calculated below.

$$\frac{\partial TE}{\partial FS} = 0.0518 \times \ln(FS) - 0.0094 \times (\ln(FS))^2$$

$$= \frac{0.0518}{FS} = \frac{0.0188 \times \ln(FS)}{FS} = 0$$

$$= -\frac{0.0188 \times \ln(FS)}{FS} = -\frac{0.0518}{FS}$$

$$= 0.0188 \times \ln(FS) = 0.0518$$

By taking the exponent of both sides:

$$(FS)^{0.0188} = 1.053$$

$$FS = 1.053^{53.19}$$

$$FS = 15.59$$

TABLE 7

Hired Labor and Productivity: Double Bootstrap Estimation

Variable	Description	Coefficients	SE	t-value
Intercept		0.7618 *	0.0391	19.4632
LnX^1	Ln of Land in acres	0.0518 ***	0.0296	1.7493
$(LnX1)^2$	Ln of Land square	-0.0094	0.0068	-1.3763
Z_1	Pesticide Cost	0.0175 *	0.0042	4.1641
Z_2	Rent on Capital	0.0156 **	0.0054	2.8768
Z_3	Family Labor Days	0.0040 *	0.0012	3.265
Z_4	Hired Labor Cost	-0.0034	0.0027	-1.2386

Source: Authors' estimation.

Note: In this procedure, 100 and 2500 iterations were used in the first and second loop, respectively, to get biased corrected DEA scores and robust estimates for the coefficients. *means 1%, **means 5%, and ***indicates 10 % significance level.

where FS means Farm Size, so according to analysis, the optimum farm size for the irrigated part of Central Punjab is 16 acres, i.e. the farm size where TE of the growth inputs becomes maximum, keeping other things constant.

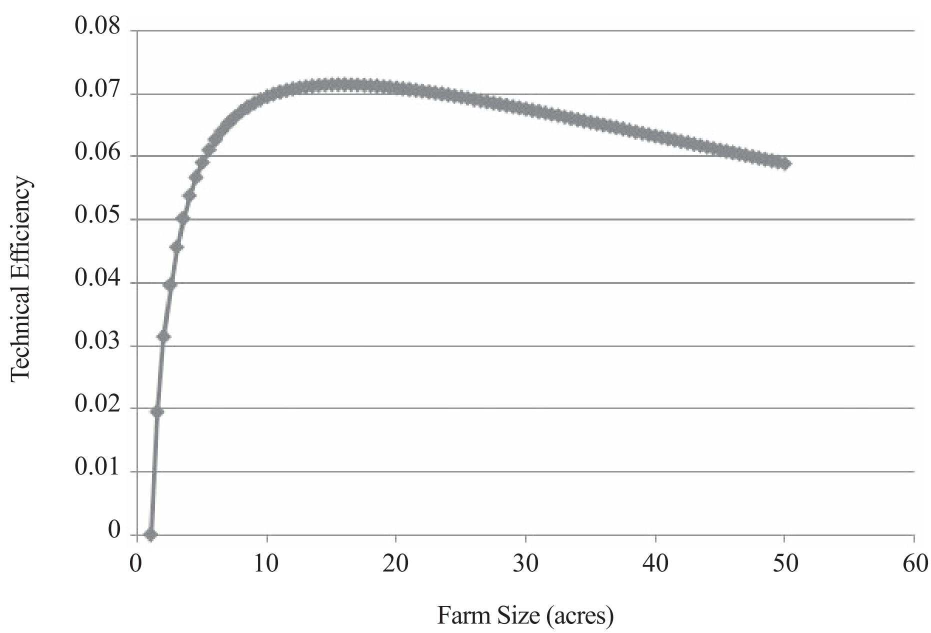

FIGURE 3

Farm Size and Productivity Relationship

V. Conclusion and Policy Implications

The research in agricultural economics indicates separability between different types of agricultural inputs because there is an agronomic asymmetry in the roles of different groups of inputs. During the production process, growth inputs are responsible for increasing the production by affecting physiological functions of the plants, e.g., the inputs like nutrients, water, seed and soil environment etc., whereas facilitating inputs affect plant growth by regulating the functions of growth inputs. Labor, pesticides, and capital are termed facilitating inputs. The present study is an analysis of the agricultural production process with a focus on the agronomic asymmetry of the roles of inputs. For this purpose, farm household-level data was used for analysis and a two-stage semi-parametric double bootstrap methodology was employed to get robust results. The first study employs this methodology in Pakistan, and the results show that pesticides, family labour, and capital are productive inputs. These variables are helping in increasing the Technical Efficiency of growth inputs and on the other side, hired labour causes to scale down the efficiency.

A policy focusing on agricultural growth and development needs special emphasis to address the issues relevant to the rural labour force and farm mechanisation. The government should provide ample credit opportunities, minimise the trade barriers that obstruct the adoption of modern technology and farm mechanisation and put efforts to expedite research and development of farm machinery. The productivity of family labour and hired labour may be increased by providing modern agricultural extension training focusing on alternate employment opportunities in the agrarian and allied sectors of the economy. Farm size and productivity is a matter of much interest for agricultural economists since Sen (1962). In the present analysis, farm size and productivity relationships are also studied. It is found that there is a quadratic type relationship between the size of the farm and productivity. The productivity of growth inputs increases initially with the increase in farm size and it starts decreasing afterwards. It is found that the optimum size of the farm in the irrigated region of Punjab was 16 acres since it was the size where TE was maximised.

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