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RESOURCE USE EFFICIENCY IN CARROT PRODUCTION AND ITS POLICY IMPLICATIONS IN THE PUNJAB, PAKISTAN

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The study estimates technical, allocative and economic inefficiencies in carrot production by employing the stochastic production frontier approach and the duality theory. The impact of determinants of technical, allocative and economic inefficiencies has also been addressed. Carrot production is concentrated in two districts, Sheikhupura and Kasur in Pakistan's Punjab, and this study is based on data collected from these two districts. Farmers are, respectively 54, 21 and 63 per cent technically, allocatively and economically inefficient. Our results reveal that a large potential exists that can be explored to increase the income of vegetable farmers in the study area. The elimination of technical and economic inefficiencies will generate an amount of 409.9 and 594.5 million rupees per year, respectively, in the province. Education, farming experience and average distance from input-output markets are found to be highly significant in order to improve technical, allocative and economic efficiency, indicating that investment on education and improvement of physical infrastructure (i.e., construction of roads) are the most critical areas that can help to eliminate inefficiencies in carrot production. This implies that investment in these sectors could play a critical role in expanding the production of carrots and to improve farm income by improving resource use efficiency in carrot production.

I. Introduction

The per capita per day consumption of vegetables in Pakistan is almost half of the recommended level of 200 grams per person per day, [Farooq and Ali (2003)]. Vegetable production is also labour intensive and thus generates higher employment than cereals at the farm level, [Abedullah, Sakham and Farooq (2002)]. Vegetables generate far higher income than the low-micronutrient staple food and also help to improve productivity and sustainability of cereal-based production system,

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[Ali and Abedullah (2002)]. Agricultural research in Pakistan has mainly focused on cereals and cash crops such as wheat, rice, cotton and sugarcane etc., and neglected the vegetable food frontier, a major contributor in maintaining productivity of the farming system. Policy makers therefore need to pay attention to improve the existing infrastructure required to grow vegetables and help sustain the farming system. Poor physical infrastructure leads to high variation of input-output prices that generates a high level of allocative inefficiency. The lack of trained human resources required to grow vegetables is assumed to be one of the major sources of technical inefficiency.

The technical, allocative, and economic efficiencies of vegetables have important implications for improving the per capita availability of vegetables in the country. Vegetable production can be increased either by increasing the allocation of area to vegetables or by improving the efficiency of existing resources allocated to its production. If vegetable farmers are technically efficient, then increase in productivity requires new inputs and technology to shift the production frontier upward. However, if significant opportunities exist to increase productivity through efficient use of existing resources and inputs with current technology, a stronger case can be made for institutional investment in input delivery, infrastructure, extension systems, farm management services, and farmers' skills; in order to promote technical efficiency of resource use at the farm level, [Ali and Chaudhury (1990)]. If allocative inefficiency is dominant then policy parameters need to stabilize the input-output prices. However, nothing can be suggested without knowing the determinants of technical, allocative and economic efficiencies.

Carrot is not only an important vegetable from an economic point of view but it also provides essential nutrients to human beings.[1] In Pakistan, the import of carrots increased many folds between 1999 and 2001. This significant increase took place because of increasing demand for carrots, within the country. Therefore, additional allocation of area for carrot cultivation or improved efficiency in carrot production can lessen the dependency on imports. At the same time, resource-use efficiency can help to spare resources (land and inputs) for other crops. It can also save foreign exchange earnings because local prices are significantly lower than the FOB prices. According to existing literature, dealing with technical, allocative and economic efficiencies in any vegetable crop has not been undertaken in Pakistan and an important sector of nutrients supply in the food chain has been ignored by researchers so far. This study attempts to fill this gap. The principal objective of the study is to estimate the technical, allocative and economic efficiencies of carrot

[1] It is a rich source of vitamin A, potassium, calcium, carbohydrates and protein. These nutrients help in functioning the liver, pancreas, spleen and particularly the lungs. Carrot is effective against all kinds of coughs and acts as a diuretic and blood thinner. It is also effective against constipation, diarrhea and chronic dysentery

production in Pakistan's Punjab, by using the stochastic production frontier approach. The impact of ownership status and other farm characteristic variables are analysed on technical, allocative and economic efficiencies in order to develop policy parameters.

The paper is organised as follows. In section II, a conceptual and analytical framework explaining technical, allocative, and economic efficiencies is discussed. Section III explains the study area and data collection procedure and delineates the empirical model with detailed specification variables. Empirical results are presented and implications are derived in Section IV and the conclusions are summarized in the Section V.

II. Conceptual Framework

Economic efficiency or cost minimization is a necessary but not a sufficient condition for profit maximization because profit maximization also requires the firm to choose the optimal level of output. Efficiency of a firm consists of two components: technical efficiency (TE), which reflects the ability of a firm to obtain maximum output from a given set of inputs, and allocative efficiency (AE), which reflects the ability of a firm to use the inputs in optimal proportions, given their respective prices. These two measures are then combined to estimate total economic efficiency (EE). The concept of technical, allocative and economic efficiencies can be illustrated by using input/input space (input-oriented measures) or output/output space (output-oriented measures), as in [Coelli (1996)] or input-output space, as in [Ali and Chaudhury (1990)].

There are two main approaches[2] to measure TE, AE, and EE. These include the stochastic frontier (parametric approach) and data envelop analysis (DEA), also known as the non-parametric approach. These two methods have a range of strengths and weaknesses which may influence the choice of methods in any particular application. The constraints, advantages and disadvantages of each approach have been discussed by Coelli (1996), Coelli and Perelman (1999). The present study uses a stochastic production frontier approach introduced by Aigner et al. (1977), and Meeusen and van den Broeck (1977). Following their specification, the stochastic production frontier can be written as:

$$y_i = F(x_i, \beta)e^{\varepsilon_i} \qquad i=1, 2, ...N \qquad (1)$$

where, y_i is output for the i-th farm, x_i is a vector of k inputs, β is a vector of (k+1) unknown parameters, and ε_i is an error term. The stochastic frontier is also called "composed error" model, because it postulates that the error term ε_i is decom-

[2] with a number of sub-options under each.

The function determining the technical inefficiency (IE) effect is defined in general form as a linear function of socioeconomic factors as:

$$IE_i = G(Z_j)$$

More details on dependent and independent variables are given in the empirical model.

III. Data Collection Procedure

Carrot cultivation is mainly concentrated in Sheikhupura and Kasur districts which occupies 25 per cent and 13 per cent, respectively, of the total area allocated to carrot production in the Punjab province (Table 1). The districts were selected on the basis of highest area allocated to carrot production. A well structured and field pre-tested comprehensive interviewing schedule was used for the collection

TABLE 1

Percentage Share of Carrot Area in Each District of Punjab

Districts	Carrot	Districts	Sarrot
Attock	0.23	Sheikhupura	25.36
Rawalpindi	0.22	Lahore	8.62
Islamabad	0.06	Kasur	13.52
Jhelum	0.16	Okara	5.07
Chakwal	0.16	Sahiwal	2.25
Sargodha	1.30	Pakpattan	0.96
Khushab	0.98	Multan	3.30
Mianwali	0.62	Lodhran	1.24
Bhakkar	0.79	Khanewal	2.97
Faisalabad	5.04	Vehari	2.06
T.T. Singh	2.76	Muzaffargarh	1.48
Jhang	2.82	Layyah	0.23
Gujrat	1.18	D.G.. Khan	0.28
M.B. Din	1.13	Rajanpur	0.50
Sialkot	1.98	Bahawalpur	1.35
Narowal	0.70	Bahawalnagar	4.22
Gujranwala	3.72	R.Y. Khan	1.58
Hafizabad	1.16	Total	100.00

Source: Government of Punjab, 2002.

of detailed information on various aspects of carrots for the year 2002-03. From each district 10 villages with a high concentration of vegetable production and 5 vegetable growers from each village were selected. A total of 100 respondents, 50 from Sheikhupura and 50 from Kasur were interviewed. On an average, they were 40 years old and had attended school for 4.5 years (Table 2).

The mean farm size was 19 acreages with a range of 2 to 175 acreages but on an average carrot was grown only on 6 acreages with a range of 0.5 to 60 acre-

TABLE 2

Variables	Sample Mean	Sample Standard Deviation	Minimum	Maximum
Household Characteristics				
Family size (No.)	7.60	3.30	2.0	18.0
Operator's age (years)	40.20	12.60	20.0	80.0
Operator's education (years)	4.50	2.90	1.0	12.0
Farm experience (years)	22.50	12.60	3.0	65.0
Tenure				
Owners (frequency)	26.00	-	-	-
Tenants (frequency)	26.00	-	-	-
Mixed (frequency)	48.00	-	-	-
Average distance from input and output market (kilometer)	11.05	4.20	1.0	20.0
Vegetable Production				
Farm size (acre)	19.10	22.60	2.0	175.0
Carrot area (acre)	6.20	7.70	0.5	60.0
Tractor hours (hours/acre)	5.40	1.40	3.0	10.0
Seed (kgs/acre)	8.40	2.30	5.0	14.0
Week of sowing (No.)	34.74	2.99	29.0	40.0
Fertilizer (NPK/acre)	34.70	21.20	0.0	103.0
Labour (days/acre)	373.10	119.80	167.0	798.0
Irrigation (hours/acre)	13.20	5.00	3.0	32.0
Yield (tons/acre)	7.50	3.90	1.3	19.8

ages. Only 32 per cent of the area was allocated to carrots indicating that farmers were diversifying their cropping activities in order to minimize risk. Of the total sample, 26 per cent of farmers cultivated their own land and 48 per cent were owners-cum-tenants. The remaining 26 per cent of the farmers were tenants. The average fertilizer (NPK) rate was 34.7 kg per acre and the range of fertilizer- use across farms varied from zero to 103 kg per acre. Labour input ranged from 167 to 798 labour-days per acre with a mean of 373 labour-days per acre. The mean irrigation time was 13 hours per acre with a range of minimum 3 to maximum 32 hours per acre.

The average carrot yield was 7.5 tonnes per acre with a range of 1.33 to 19.8 tonnes per acre. High variation in yield could be due to difference in management practises, planting time, soil quality, random shocks, etc. This considerable gap of around 18.5 tonnes per acre between average and highest farm yield suggests that there are opportunities for increasing carrot yields from a given set of technology and resources. To investigate the question of how great a gap is due to technical inefficiency and constraints beyond the farmers control (such as soil and weather constraints), further empirical analysis is required.

Empirical Model

In order to select the best specification of the production function; tests of hypotheses for the parameters of the frontier model was conducted by using the generalized likelihood-ratio statistic "LR" defined by:

$$LR = -2\ln [L(H_0) / L(H_1)] \qquad (10)$$

where, $L(H_0)$ is the value of the likelihood function for the frontier model, in which the parameters' restrictions specified by the null hypothesis, $H_0 = \beta_{ji} = 0$, are imposed; and $L(H_1)$ is the value of the likelihood function for the general frontier model. If the null hypothesis is true, then "LR" has approximately a chi-square (or mixed chi-square) distribution with degrees of freedom equal to the difference between the number of parameters estimated under H_1 and H_0, respectively. The Cobb-Douglas (CD) and translog production functions was used and on the basis of the test statistic it was found that CD is the best fit for data set. Therefore, the conclusion developed from the null hypothesis assumes that the values for the coefficient of interaction terms and square terms are zero, is accepted. The Cobb-Douglas production function was selected on this basis.

In addition to the above evidence, the Cobb-Douglas (CD) functional form (beside its restrictive properties) is used because it is self-dual and its dual cost frontier model provides a basis for estimating allocative and economic efficiency. It also provides an adequate representation of the production process as interest lies

on efficiency measurement and not an analysis of the production structure [Taylor and Shonkwiler (1986)]. Further, the CD functional form is self dual[5] and has been widely used in the farm efficiency analysis.[6] The stochastic production frontier (as given below) for carrots is empirically estimated by applying the maximum likelihood estimation technique:

$$\ln y_i = \ln \beta_0 + \sum_{j=1}^{6} \beta_j \ln x_{ij} + v_i - u_i \qquad (11)$$

where,

y_i = yield of vegetable of the i-th farm in kg/acre,

β_0 is intercept and $\beta_{j's}$ are response parameters or elasticity corresponding to each input,

x_1 = tractor hour/acre,

x_2 = seed in kg/acre,

x_3 = family and hired labour used for all activities except for harvest in days/acre,

x_4 = active nutrients of nitrogen, phosphorus and potassium i.e., sum of N, P, and, K, NPK in kg/acre,

x_5 = hour of irrigation/acreage,

x_6 = district dummy, if Sheikhupura = 1 otherwise zero,

v_i = a disturbance term with normal properties as explained above,

u_i = farm specific error term as defined in equation (2).

The model is estimated on per acreage basis by using the Frontier Version 4.1 developed by Coelli (1994). There are two reasons for estimating on per acreage basis: first, it is intuitively simpler to directly interpret efficiency on a per unit area as opposed to per plot basis; second, farm size is collinear with other variables included in the model.

The error terms v_i and u_i are then found from the stochastic frontier model and technical efficiency predictor by replacing parameters with their maximum likelihood estimates. Subtracting v_i from both sides of equation (11) and by replacing β's

[5] The dual of the translog stochastic frontier is intractable, that is, it is not feasible to derive the dual cost function from our cost decomposition technique and hence we can not obtain technical allocative and economic efficiencies.

[6] The statement can be supported by the empirical literature reviewed in Battese (1993), and in Bravo-Ureta and Pinheiro (1993). Kebede, (2001) and Bravo-Ureta and Pinheiro (1997) also employed a similar functional form. Further, different studies concluded that the choice of the functional form might not have a significant impact on measured efficiency levels [Wadud (1999); Ahmed and Bravo-Ureta (1996); Good et al. (1993)].

with maximum likelihood estimates ($\beta^{\circledast}$'s) yields:

$$\ln \dot{y}_i = \ln y_i - v_i = \ln\beta_0^{\circledast} + \sum_{j=1}^{6} \beta_j^{\circledast} \ln x_{ij} - u_i \qquad (12)$$

where, $\dot{y}_i$ now represents the farm's observed output adjusted for the stochastic random noise captured by v_i [as explained in equation (4)]. The farm specific technical efficiency is estimated by using the relation as discussed in equation (5) and for this specific empirical model it is given below:

$$TE_i = \exp(-u_i) = [y_i / \{(\beta_0^{\circledast} \prod_{j=1}^{6} x_{ij}^{\beta_j^{\circledast}}) e^{v_i}\}] \qquad (13)$$

By employing Shephard's (1953) Lemma, the dual cost frontier (function of input prices), output and the parameters of the production function, are developed as:

$$c(w_{ij}, \dot{y}_i, \beta_j^{\circledast}) = \alpha_0 \prod_{j=1}^{6} w_{ij}^{\beta_j^{\circledast}\alpha} \dot{y}_i^{\alpha} \qquad (14)$$

where "c" stands for cost function, and

$$\alpha_0 = [1/\beta_0^{\circledast\alpha}] [1/(\prod_{j=1}^{6} \beta_j^{\beta_j^{\circledast}\alpha})]$$

and

$$\alpha = [1 / (\sum_{j=1}^{6} \beta_j^{\circledast})]$$

Now by differentiating equation (14) with respect to each input price and by applying Shepard's Lemma, the economically efficient level of inputs is derived as:

$$x^E_{ij}(w_i, \dot{y}_i, \beta^{\circledast}) = \alpha_0(\beta_j^{\circledast}/w_{ij})\dot{y}_i^{\alpha} \prod_{j=1}^{6} w_{ij}^{\beta_j^{\circledast}\alpha} \qquad (15)$$

The economically efficient input vector x^E_{ij} is obtained by substituting the input price vector and output in equation (15)[7]. Multiplying economically efficient vector x^E_{ij} by the input price vector generates the economically efficient cost of production ($w_{ij}x^E_{ij}$) of the i-th farm and this is further used to develop Economically Efficient (EE) indices for the i-th farm as follows:

$$EE_i = (w_{ij}x^E_{ij} / w_{ij}x_{ij}) \qquad (16)$$

The TE is obtained by using equation (13) and EE by employing equation (16) to estimate AE as per equation (9).

Education and farm experience are important variables that help to improve the managerial ability of the farmer and both are expected to play a positive role in the improvement of technical, allocative and economic efficiency. It supports the hypothesis that education and experience are basically inputs that are useful for dealing with rapid changes in farming system. Both have therefore included in technical inefficiency effect model.

The impact of farm size is ambiguous on inefficiency. The large planting area is likely to have negative effects on inefficiency because the larger the planting area, the greater is the likelihood of applying modern technologies, such as, tractors and irrigation. Another group of researchers argues that small farmers could be more efficient in utilizing the limited available resources for their survival because of economic pressure. Therefore, it might not be appropriate to correlate farm holding with inefficiency especially in the case of vegetable production because farmers allocate only a small portion of their total land to vegetable cultivation. Hence, the area allocated to carrot production is selected to correlate with technical inefficiency.

In the existing literature there is continuous debate whether owners are more efficient than tenants or vice versa. An attempt has been made to address this issue in vegetable production.

The farm specific technical inefficiency ($IE = 1 - TE_i$) is considered as a function of six different variables and the inefficiency effects model is formulated as:

$$IE_i = \delta_0 + \sum_{j=1}^{6} \delta_j Z_{ji} \qquad (17)$$

where δ_0 is the intercept term and δ_j is the parameter for the j-th explanatory variable, and:

Z_{1i} = number of years of schooling attended by the farm decision maker,
Z_{2i} = farming experience (number of years since he/she has been farming),
Z_{3i} = area allocated to carrot production in acre,
Z_{4i} = number of planting weeks (1 to 52) in the year,
Z_{5i} = owner's dummy (if owner then Z_{5i}=1, otherwise zero),
Z_{6i} = average distance (in kilometers) from input-output market.

Both education and farming experience are for the household head because he is the one who mostly makes all decisions. In case where the head is not economically active the person in the family who makes decisions at the farm is considered.

The study also investigates the impact of these variables on allocative and economic efficiency by applying the same model but allocative and economic efficiency as the dependent variable.

IV. Results and Discussion

The hypothesis whether the Cobb-Douglas production function is an adequate representation of the data was tested, given the specifications of the translog model. Alternatively, it was also tested that coefficient of interaction and square terms in the translog production function were zero.[8] The values of the log likelihood for the Cobb-Douglas and translog production functions are −39.33 and −37.11, respectively. Through equation (10) we estimated the value of LR equals to 4.44. This value is compared with the upper 5 per cent points for the χ^2_{15} distribution, which is 25.0. Thus, the null hypothesis that the Cobb-Douglas frontier is an adequate representation of the data is accepted, given the specifications of the translog frontier.

The study employed the Frontier 4.1 programme developed by Coelli (1994) to estimate the coefficient of production function and inefficiency effect model by choosing the option of inefficiency effect model.[9] The results of Maximum Likelihood Estimates (MLE) for the Cobb-Douglas production function (under the assumption of half normal and truncated distribution) are reported in Table 3. A log likelihood ratio test statistic was applied to select the distribution and it was found that truncated distribution fits the data set bestles. Therefore, further discussion and estimates of allocative and economic efficiency is based on the coefficients of production function (MLE) reported under the truncated distribution. As expected the signs of all the variables in the production function are positive. The Cobb-Douglas production function parameters can be illustrated as output elasticity. The parameters of tractor hours, labour and irrigation hours are highly significant and hence, play a major role in carrot production. The elasticity of labour was highest among all variables in the model and supports the hypothesis that vegetable production was labour intensive. The district dummy was included in the production function to capture the resource based differences (soil type, temperature during the production season, etc.,) in two districts and was found to be highly significant, implying that resources in Sheikhupura district was more conducive for carrot production than the Kasur district.[10] Significantly higher average yield for the district

[8] Both functions were estimated but in order to maintain length of the paper, the results are reported only for the Cobb-Douglas production function.

[9] This option allows Frontier 4.1 to estimate the coefficient of production function (MLE) and inefficiency effect model in one step as proposed by Wang (2002).

[10] The model with variety of dummies was tried to capture the technological differenees among farmers but no variety dummy was significant even at the 15 per cent level and therefore, it was excluded.

TABLE 3

Maximum Likelihood Estimates with Cobb Douglas Stochastic Frontier Function under the Assumption of Half Normal and Truncated Distribution

Variable	Half Normal Distribution	Truncated Distribution
Intercept	6.51^{***} (0.71)	6.97^{***} (0.86)
Ln(Tractor hours)	0.18^{ns} (0.18)	0.17^{***} (0.08)
Ln(Seed)	0.48^{***} (0.17)	0.24^{ns} (0.36)
Ln(Labour)	0.23^{***} (0.10)	0.35^{***} (0.14)
Ln(Fertilizer, NPK)	0.06^{ns} (0.09)	0.01^{ns} (0.08)
Ln(Irrigation hours)	0.18^{**} (0.11)	0.12^{***} (0.04)
District Dummy	0.19^{**} (0.09)	0.22^{***} (0.09)
σ^2_s	0.19^{***} (0.05)	0.16^{***} (0.03)
Γ	0.92^{***} (0.06)	0.99 (0.01)
Log Likelihood function	-43.97	-39.33
LR test of the one-sided error	23.86	33.15

Figures in parenthesis are standard errors.
*** and ** indicates significance at 5 and 15 per cent probability level, respectively, while ns stands for non-significant.

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Ln(Fertilizer, NPK)	0.06ns (0.09)	0.01ns (0.08)
Ln(Irrigation hours)	0.18** (0.11)	0.12*** (0.04)
District Dummy	0.19** (0.09)	0.22*** (0.09)
σ^2_s	0.19*** (0.05)	0.16*** (0.03)
Γ	0.92*** (0.06)	0.99 (0.01)
Log Likelihood function	-43.97	-39.33
LR test of the one-sided error	23.86	33.15

Figures in parenthesis are standard errors.
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of Sheikhupura in the farm sample also supports this argument. The coefficient of fertilizer and seed have a positive sign but are not significant.

The value of γ is 0.99 with estimated standard error of 0.01 (Table 3). It is consistent with the theory that true γ-value should be greater than zero. The value of γ-estimate is not significantly different from one, indicating that random error does not explain the variation in carrot yield. This is against the general expectation because in the case of agriculture, uncertainty (risk), is a main source of variation. This implies that the stochastic frontier model is not significantly different from the deterministic frontier for the sample of farms but this may not always be true. However, it should be noted that 99 per cent variation in yield is due to technical inefficiency and only one per cent is due to stochastic random error.

The value of log likelihood ratio test (LR value) reported in Table 3 is estimated in Frontier 4.1 by using log likelihood function for OLS and MLE, as follows: LR = $-2*[-55.91 - (-39.33)] = 33.15$. When compared with critical value (Table 1), Kodde and Palm (1986), the null hypothesis of no technical inefficiency effects in carrot production is rejected.

TABLE 4

Frequency Distribution of Technical, Allocative and Economic Efficiency for Individual Farms

Efficiency Interval	TE Frequency	AE Frequency	EE Frequency
0.800<E<1.000	7.00	45.00	0.00
0.700<E<0.800	6.00	33.00	2.00
0.600<E<0.700	14.00	18.00	10.00
0.500<E<0.600	10.00	2.00	17.00
0.400<E<0.500	14.00	2.00	9.00
0.300<E<0.400	25.00	0.00	15.00
0.200<E<0.300	18.00	0.00	25.00
0.100<E<0.200	6.00	0.00	22.00
Average	0.46	0.79	0.37
Minimum	0.16	0.45	0.08
Maximum	0.99	1.00	0.79

Economic and allocative efficiency is estimated through equations (16) and (9), respectively, and the results of average efficiencies and frequency distribution are reported in Table 4. Mean technical, allocative and economic efficiency in carrot production is 46, 79 and 37 per cent, respectively. Overall, economic efficiency is very low but technical inefficiency contributes a major share of economic inefficiency. Allocative inefficiency is 21 per cent but technical inefficiency is 54 per cent.

The results of technical, allocative and economic inefficiency effect model are reported in Table 5. In case of technical, allocative and economic inefficiency it is

TABLE 5

Estimates of Inefficiency Effect Model

Inefficiency model	TIE	AIE	EIE
Intercept	2.58*** (0.88)	0.29^{ns} (0.26)	1.24*** (0.28)
Education	-0.06*** (0.01)	-0.01*** (0.00^{+})	-0.02*** (0.01)
Farming experience	-0.01*** (0.00^{+})	-0.01*** (0.00)	-0.00** (0.00^{+})
Carrot area	-0.01*** (0.00^{+})	0.00^{ns} (0.01)	-0.00** (0.00^{+})
Week of sowing	-0.18*** (0.03)	-0.04** (0.02)	-0.07*** (0.03)
Owners	0.20** (0.11)	-0.08** (0.06)	0.11*** (0.03)
Average distance from market	0.02*** (0.01)	0.01*** (0.00^{+})	0.01*** (0.00^{+})
Log likelihood function	-39.33	88.36	50.99

Figures in parenthesis are standard errors and standard error with + superscript indicating that values are zero after rounding.
*** and ** indicates significance at 5 and 15 per cent probability level respectively, while ns shows non-significant.
AIE and EIE stand for allocative inefficiency and economic inefficiency, respectively.

observed that education and farming experience are highly significant with a negative coefficient. This implies that they contribute significantly to improving technical, allocative and economic efficiency in carrot production. The conclusion of positive association between education and technical efficiency is consistent with Lockheed, Jamison, and Lau (1980), Ali and Flinn (1989), Lingard, Castillo and Jayasuriya (1983), Bravo-Ureta and Pinheiro (1997), and Kebede (2001). Therefore, targeting extension programmes to the needs of less educated farmers and to improve the access to education in rural areas may have high returns in terms of high yield.[11] Lingard, Castillo and Jayasuriya (1983) and Kebede (2001) used Farmers' age as a proxy variable for experience. Their conclusion that farming experience improve technical efficiency significantly is consistent with our findings.[12]

The results show that the coefficient of area (allocated to carrot plantation) is negative and highly significant indicating that cultivation of carrot on larger lots will help to reduce technical inefficiency in carrot production mainly because on a larger area it is more economical and convenient to adopt modern tools of farming. The results are consistent with the findings of Kaiser (1988) and Alvarez and Arias (2004). However, most of the studies in under developing countries did not observe a significant correlation between farm size and technical efficiency [Squires and Tabor (1991), Bravo-Ureta and Eveson (1994), and Bravo-Ureta and Pinheiro (1997)]. A correlation between cropped area and allocative efficiency is not found.

We attempt to study the impact of sowing time on technical, allocative and economic inefficiency results show that as farmers delay the sowing of carrots it helps to reduce all three kinds of inefficiency. The negative impact on technical inefficiency might be due to the availability of more favourable temperature required for carrot production at a later stage. The significant and negative coefficient of planting time in allocative inefficiency is somewhat surprising but a logical reason exists to explain it. The time of harvest for carrots and plantation of wheat is the same in the study area and wheat is a major cereal crop that plays a significant role in providing food security to the farm families. Delay in the carrot harvest may lead to a decline in area allocated to the wheat crop. Hence, limited available resources (family labour) required for both crops (harvesting of carrot and plantation of wheat) compete with each other. This helps to explain why delay in the plantation of carrot improves allocative efficiency. Now the question is why farmers do not delay plantation of the carrot crop in order to improve the productivity of employed resources? The study investigated this issue and found that there was a high fluctuation in the output prices overtime, which continued to decline with delayed harvest (see Figure 1). This implies that there is a trade-off between low yield and high prices and both cannot be achieved at the same time. Secondly, delay in plantation leads to delay in harvest of carrots and it will not allow the farmers to use the same piece of land for wheat crop. Again, there is a trade-off between opportunity cost of land (forgone profit if wheat is not grown) and higher efficiency in carrot production. Hence, those farmers who decide to use their piece of land for the wheat crop will go for early plantation. This allows them to get higher prices but at the cost of low technical and allocative efficiency.

11 Bravo-Ureta and Pinheiro (1997) finds a negative impact of education on allocative and economic efficiency but the coefficients are not significant.

12 Bravo-Ureta and Pinheiro (1997) did not find significant impact of age on technical, allocative and economic efficiency.

The impact of ownership (property rights) on inefficiency are analysed through an owner dummy in the efficiency effect model. The coefficient of ownership is positive and statistically significant (although only at 15 per cent probability level) implying that owners are technically less efficient than owner-cum tenants and tenants but in case of allocative efficiency owners are more efficient than the other two groups. This may be due to the reason that owners have better transportation facilities because they possess their own transport (such as tractors, motor bikes, etc). In the case of economic efficiency, again owners are less efficient simply

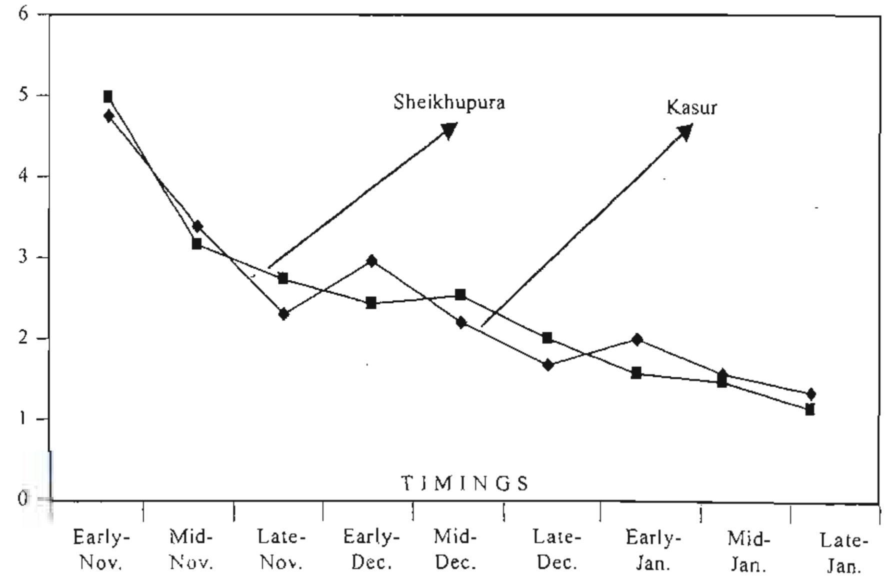

Figure 1

Average Prices of Carrot (Rupees per kg)[13]
Over the Period 2000-2004 in Two Districts

13 US$ one = Rs. 60/-

because it is a multiplication of technical and allocative efficiency and coefficient of owner dummy in technical efficiency plays a dominant part in determining economic efficiency. The results of the study contradict the findings of Reddy (2002) where he concluded that tenants have lower technical efficiency than owner operated farms. They, however confirm that well defined property rights do not have a significant impact on technical and economic efficiency in vegetable production.[14]

The coefficient of average input-output market distance is positive and significant in the case of all three inefficiencies, implying that improvement in the marketing system (development of small markets in villages, construction of new roads, etc), is expected to contribute to an improvement in technical, allocative and economic efficiency in carrot production.[15]

The results of the study show that an improvement in technical efficiency will yield an additional 8.8 tonnes of carrot per acreage. The total area in the province of Punjab under carrot production is 17,745 acreages and improvement in technical efficiency will enhance carrot production from 133,087 tonnes to 289,320 tonnes per year. This additional 156,233 tonnes of carrots will raise Rs.409.9 (US$ 6.8) million of revenue to the province each year. However, improvement in economic inefficiency is expected to generate an amount of Rs.594.5 (US$ 9.9) million per year to the province. The results clearly demonstrate that substantial potential exists to increase resource use efficiency in carrot production. Therefore, in order to narrow the gap between supply and demand, future strategy should be based on efficiency improvement rather than expansion of area. If similar results are found in the production of other vegetables then it implies that improvement in resource use efficiency can contribute tremendously to improve revenue at the farm level.[16]

V. Concluding Remarks

In contrast to efficiency in cereal production, the results of this study shows that technical and allocative inefficiency exists in carrot production and technical inefficiency is dominant over allocative inefficiency. This implies that technical inefficiency contributes a major share of economic inefficiency. Economic efficiency is only 37 per cent indicating that a large potential exists which can be explored by improving resource use efficiency in carrot production. This improvement in resource use efficiency will generate an additional Rs.594.5 (US$ 9.9) million in the province while simply by making the farmers technically efficient will generate an additional Rs.409.9 (US$ 6.8) million per year in the province.

Our results show that education can play a significant role in improving technical, allocative and economic efficiency in carrot production. It suggests that by augmenting financial resources in the education sector resource use efficiency in carrot production can be improved. Improvement of roads and the marketing system is another important area for investment that can help to reduce technical, allocative and economic inefficiency.

The above conclusions are valid only for carrot production in Pakistan and may not be true for other crops as well as other regions for the same crop. However, it will be quite useful to conduct a comprehensive study dealing with a complete farming system to develop a clear-cut policy for vegetables, a neglected food frontier in Pakistan. Such information will facilitate policy managers to draw up a balance in resource allocation for vegetable and cereal crops.

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[14] This conclusion might not be valid for other crops and in other regions.

[15] It seems odd to argue that improvement of infrastructure can improve technical efficiency but in fact it is still possible. However, ehnancement in the marketing system can improve the delivery of timely inputs (fertilizer, pesticide, etc.,) and it will enhance the productivity of these resources which is cxpected to appear in terms of high technical efficiency.

[16] This however, requires improvement in the extension system, physical infrastrueture (roads and development of rural markets), and the establishment of more schools in rural areas. Development of such infrastructure requires substantially higher amounts of resources than the expected benefits achieved from the improvement in carrot production. However, in order to depend on the cost-benefit analysis approach we need to estimate the benefits of such infrastructure for other crops and its multiplier effect on other sectors of the economy. It is only a partial analysis for one crop and the credibility of our work can be improved by expanding the analysis to a complete farming

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