An Analysis of the Sources of Wheat Output Growth in the *Barani* Area of the Punjab[1]

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A time-varying efficiency effects approach using district level data of wheat in *barani* Punjab is used to disintegrate wheat output growth into different sources. The results show that wheat output grew at an annual rate of 2.71 percent under *barani* conditions, during the period of study. Technological change was the main driving force, sharing about 107 percent of this growth, while the changing inputs contributed negatively by about 10 percent and the efficiency contribution was less than 4 percent. On the other hand, irrigated output increased by about 4.7 percent per annum in the region; of which 65 percent, 1.3 percent, and 34 percent were attributable to technological change, change in efficiency, and increase in inputs. As regards the overall wheat output in the *barani* region of the Punjab, it grew at an annual rate of 2.97 percent—84 percent of which was shared by the *barani* lands and the remaining 16 percent was contributed by irrigated lands in the region.

One common result which was observed under both *barani* and irrigated conditions was that the productivity growth (the sum of technological and efficiency change) showed declining trends exclusively due to negative trends in technical efficiency. Low relative profitability as compared to growing vegetables and raising livestock might be the main cause of this trend in the *barani* area: the same reason could also be a source of decline in efficiency. Rapid technological advancements require that farmers and administrators improve their management skills even to keep the productive efficiency at the same level. This is not possible without education and training along with a more effective flow of information [Lall (1993)]. Under these circumstances, the agricultural extension system has to play a greater role in assisting the farming community in the *barani* areas so as to adopt and use new technologies more rationally.

1. INTRODUCTION

Agriculture is the largest sector of Pakistan economy. It accounts for about 24 percent of the GDP of Pakistan. It provides employment to more than 50 percent of

[1]The term 'barani' refers to the agricultural area that depends on rainfall for cultivation. The word 'barani' comes from the Persian word 'baran' meaning 'rain' [Qureshi (1963)].

the labour force and contributes directly or indirectly to about 70 percent to the total export earnings of the country. The agriculture sector has two main components, which are crop production and livestock products. Crops share about 70 percent of the agricultural GDP and the remaining 30 percent comes from the livestock sector.

A large number of crops are grown in Pakistan: the most important of them are wheat, rice, cotton, and sugarcane, which jointly contribute nearly 75 percent to the value-added from the crop sector. Among these, wheat is at the top in terms of its share both in value-added and cropped area, which are 33 percent and 42 percent respectively [Pakistan (1998)].

The Punjab province dominates in wheat production and shares more than 70 percent both in area and output. About one-fifth of the cultivated area of Punjab is rainfed and the most fertile region is the Pothwar, which is located north of the Salt Range stretching from the river Jehlum to the river Indus. It covers the areas of Attock, Rawalpindi, Jehlum, and Chakwal. It shares about 10 percent of the wheat area in Punjab. Despite low yield, it contributes about 6 percent to the total wheat production of the province. This contribution makes the difference between self-sufficiency and import for the country. Therefore, the development of the rainfed area is very important for the country's food security.

To exploit the full potential of the *barani* lands, the Government of Pakistan has initiated a number of measures which are mentioned here briefly. Apart from input-output price incentives, infrastructure development, agricultural extension, etc., the government efforts include the establishment of a National Agricultural Research Centre, the Barani Agricultural College—to be raised to university level, the Agency for Barani Area Development, etc., whose mandate is to work solely in *barani* area agriculture. Due to these efforts, the Pothwar area experienced significant increase in wheat yield in the last three decades, i.e., 150 kg/hac in 1970-71 to almost 600kg/hac in 1996-97. As a consequence, total production of this area increased considerably during this period.

It is to be noted that the tubewell irrigation in the Pothwar region has increased over time: the share of wheat area under irrigation increased from 4.7 percent in 1971 to 7.3 percent in 1997. Thus, the overall increase in wheat output is partly fuelled by the popularity of tubewell irrigation in the region.

Two main sources that could lead to expansion in agricultural production are productivity growth and the use of additional factors of production [Ahmad and Bravo-Ureta (1995)]. Productivity has two constituents: technological change and technical efficiency [Good *et al.* (1993)]. Research and development is considered to be the main force behind technological change, while, education, experience, and expanded infrastructure are consequential for improving the system's efficiency [Kalirajan (1991) and Fan (1991)].

The major objective of this paper is to analyse the *barani* wheat output growth from three perspectives: technological change, technical efficiency, and input

growth. At present, about 7 percent of the total wheat area in Pothwar is under well irrigation and, thus, a similar analysis is also conducted to compute irrigated wheat share in the overall growth of the region.[2] This study is the first attempt to decompose wheat output growth into these components using Pakistani data.[3] The remaining paper is arranged in three sections. Section 2 deals with the methodological issues and estimation procedure. Section 3 presents the variable definitions and data. The results are discussed in Section 4, while concluding remarks are given in Section 5.

2. FRONTIER ANALYSIS AND OUTPUT GROWTH

Farrell (1957) initially introduced the frontier function technique. This original work was of a non-parametric type. It was extended to parametric techniques, including deterministic and stochastic models for the measurement of efficiency. The deterministic models were initiated by Aigner and Chu (1968) and further extended by Timmer (1970, 1971); Afriat (1972); Richmond (1974); Schmidt (1976) and Greene (1980). The main drawback of the deterministic model is that it does not allow the possible effects of the factors that are not under the control of the producer. Consequently, all deviations from the frontier can be regarded as inefficiency, resulting in an over-estimation of this component [Meeusen and van den Broeck (1977)].

To avoid this problem the stochastic frontier model was independently developed by Aigner, Lovell, and Schmidt (1977) and Meeusen and van den Broeck (1977). This model appends an error term, assuming two components: one is symmetric, capturing statistical noise and random shocks, and the other is one-sided, representing technical inefficiency effects. This approach was initially developed for the analysis of cross-sectional data. However, it was later expanded to analyse

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[2]We thank the anonymous referee for this suggestion after reading the first version of the paper.

[3]An only exception is a study published in this journal is by Karamat and Hameed (1996) which used aggregate country level data of both agriculture and manufacturing sectors of Pakistan. The efficiency component was not properly estimated in this study. Estimation of time variant technical efficiency and its changes over time involve some further steps: the authors stopped at Equation 4 (in the present paper), while to compute technical efficiency and the changes over time one has to proceed through Equations 5 and 6. Other study using aggregate level data for Pakistan agriculture related to total factor productivity and technical change analysis is by Wizarat (1981). These studies do not incorporate the efficiency component in their analyses.

Qureshi (1963) analysed the impact of rainfall on acreage and production in the *barani* area of West Pakistan (using the data from Pothwar area). No other independent variable was included in the analysis. However, the results, though old, could provide an interesting comparison to that of the present study. Recently, Mahmood (1995) and Himayatullah (1995) used cross-sectional data for *barani* wheat. Mahmood (1995), using the profit function approach, concluded that *barani* farming is subject to risky conditions and thus the objective function in this situation is to ensure food security rather than pursuing the economic efficiency, and *barani* farming is subject to constant returns to scale. Himayatullah (1995) concluded that the medium-sized farms are more efficient than small and large farms. This study further concludes that among the tenurial status farms, owner-operated farms have higher productivity than the other categories.

balanced [e.g., Pitt and Lee (1981) and Battese and Coelli (1988)] and unbalanced [e.g., Battese, Coelli and Colby (1989) and Seale (1990)] panel data. All of these studies relied on the assumption that technical efficiency does not vary over time. Kumbhakar (1990) relaxed this assumption using balanced panel, while Battese and Coelli (1992) extended this approach to accommodate unbalanced panel data.

The stochastic frontier models are not free of criticism. These models require distributional assumptions regarding the composed error term to separate efficiency from statistical noise and thus have the tendency to produce different efficiency measures [Schmidt and Sickles (1984)]. Additionally, this technique does not allow the likely association between technical efficiency and the other variables included in the frontier function. These problems can be taken care of by using the fixed effects model [Gong and Sickles (1989) and Schmidt and Sickles (1984)].

Hoch (1955) pioneered the fixed effects technique: its subsequent extensions could be found in Hoch (1958, 1962); Mundlak (1961, 1978) and Schmidt and Sickles (1984). All of these developments were based on the assumption that technical efficiency is time-invariant. However, Mundlak (1978) was the first who proposed that this assumption could be relaxed. Recently, Cornwell, Schmidt, and Sickles (1990) formally developed a fixed effects technique that allows the firm effects to vary over time. The same technique has been applied for the analysis of data in this paper.

Among the numerous functional forms, the most widely used in the empirical studies relating to efficiency are the translog and Cobb-Douglas forms [Bravo-Ureta and Pinheiro (1993) and Battese (1992)]. The Cobb-Douglas functional form is used for the analysis in this study,[4] which can be written as

$$LnY_{it} = \alpha + \Sigma_k \beta_k lnX_{kit} + \gamma T + \varepsilon_{it} \qquad \ldots \qquad \ldots \qquad \ldots \qquad \ldots \qquad (1)$$

Where subscripts i, t, and k represent the ith firm (here district), time and inputs, respectively; Y_{it} denotes output and X_{kit} stands for kth input; T is smooth time representing technological change; ln denotes natural log; and α, β and γ are the unknown parameters to be estimated. The term $\varepsilon_{it} = U_i + V_{it}$ is a composed error term: where V_{it} is stochastic random variable representing factors which are not under the control of the producer, which is assumed to be independent and identically distributed with mean zero and constant variance; and U_i is an indicator of technical efficiency [Greene (1990)]. Following Mundlak (1961) and Hoch (1962), along with the assumption that technical efficiency is to remain constant over time, Equation 1 can be rewritten as

$$LnY_{it} = \alpha + \Sigma_k \beta_k lnX_{kit} + \gamma T + \Sigma_i \delta_i D_i + V_{it} \qquad \ldots \qquad \ldots \qquad \ldots \qquad (2)$$

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[4]The translog production function was also estimated which resulted into several violations of regularity conditions. However, the results of some of the empirical studies also show that technical efficiency measures are unaffected by alternative functional forms [e.g., Ahmad and Bravo-Ureta (1996)].

Where D_i is a district-specific dummy variable having a value of 1 for the ith district and 0 otherwise. The model given in Equation 2 can be estimated using analysis of variance technique or least squares with dummy variables [Greene (1990)]. The δ_i can be used to compute firm-specific technical efficiency as $TE_i = exp(\delta_i)/max[exp(\delta_i)]$.[5]

Following Mundlak's (1978) proposal, U_i in Equation 2 can be replaced with $\theta_i + \rho_i T$ in order to allow the firm effects to vary over time. However, Cornwell, Schmidt, and Sickles (1990) suggested the following function

$$U_{it} = \theta_i + \rho_i T + \lambda_i T^2 \qquad \ldots \qquad \ldots \qquad \ldots \qquad \ldots \qquad \ldots \qquad (3)$$

Where θ_i is a district-specific intercept, ρ_i is district-specific parameter with respect to time, and λ_i is a firm-specific parameter with respect to time squared. Following Cornwell, Schmidt, and Sickles (1990), time-varying technical efficiency can be estimated in two steps. In the first step, residuals (ε_{it}) are derived using OLS from Equation 1 [Fecher and Pestieau (1993)]. In the second step, ε_{it} is regressed on district-specific dummies, time, and their combination, as follows:

$$\varepsilon_{it} = \Sigma_i\theta_iD_i + \Sigma_i\rho_iD_iT + \Sigma_i\lambda_i D_i T^2 + V_{it} \qquad \ldots \qquad \ldots \qquad \ldots \qquad \ldots \qquad (4)$$

where $V_{it} \sim N(0, \sigma_v^2)$. The predicted values from Equation 4 (i.e., U_{it}) are then used to calculate TE measures at all data points as follows:

$$TE_{it} = exp(U_{it})/max[exp(U_{it})] \qquad \ldots \qquad \ldots \qquad \ldots \qquad \ldots \qquad \ldots \qquad (5)$$

where $max[exp(U_{it})]$ is the highest fitted value in the tth time period.

The model just discussed is further used to disintegrate the sources of wheat output growth in the Pothwar area of Punjab. These sources of growth are the size effect, technological change, and technical efficiency. For the purpose of exposition, the estimated Cobb-Douglas production function in a simplified version can be written as

$$lnY = ln\hat{B}_t + lnT\hat{E}_{it} + \sum_k \hat{B}_k lnX_{Kit} \qquad \ldots \qquad \ldots \qquad \ldots \qquad \ldots \qquad (6)$$

The right-hand side of this equation shows three components. The first component, $ln\hat{B}_{it}$, stands for technological change and is equal to $\hat{\alpha} + \hat{\gamma} T$. The second term, $lnT\hat{E}_{it}$, represents technical efficiency. The third expression, $\sum_K \hat{B}_K lnX_{Kit}$, is the size effect. The total derivative of Equation 6 with respect to time produces

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[5]Technical efficiency (*TE*) of a production unit (here, district) is a ratio of observed output to the maximum achievable output, at the given level of inputs [Lovell (1993)]. If *TE* =1, the productive unit is on the frontier of the production function and thus is 100 percent technically efficient. The *TE*<1 means that the productive unit lies below the frontier production function and consequently produces less than the maximum potential output. So, to achieve the maximum possible output, more inputs have to be used —which in turn involve a higher cost.

$$\frac{dlnY_{it}}{dT} = \frac{\partial ln\hat{B}_t}{\partial T} + \frac{\partial ln\hat{E}_{it}}{dT} + \sum_K \hat{B}_K \frac{\partial lnX_{Kit}}{dT} \qquad \ldots \qquad \ldots \qquad \ldots \qquad (7)$$

In simple notations, the above equation can be rewritten as

$$\frac{\dot{Y}}{Y} = \frac{\dot{B}}{B} + \frac{T\dot{E}}{TE} + \sum_K \hat{B}_K \left(\frac{\dot{X}}{X}\right) \qquad \ldots \qquad \ldots \qquad \ldots \qquad \ldots \qquad \ldots \qquad (8)$$

The dots in Equation 8 indicate time derivatives. The term on the left-hand side of this equation, $\dot{Y}/Y$, stands for output growth. This, in turn, is composed of technological change ($\dot{B}/B$), change in technical efficiency ($T\dot{E}/TE$), and change in the level of inputs or size effect [$\sum_K \hat{B}_K (\dot{X}/X)$]. From the estimated model, all of these three sources of growth can be obtained as follows: (1) $\hat{\gamma}$ approximates the technological change component, $\dot{B}/B$; (2) $lnT\hat{E}_{it} - lnT\hat{E}_{it-1}$ yields the change in technical efficiency, $T\dot{E}/TE$; and (3) the expression $\sum_K \hat{B}_K (lnX_{Kit} - lnX_{Kit-1})$ is used to estimate the size effect, $\sum_K \hat{B}_K (\dot{X}/X)$.

The above procedure is used separately for the non-irrigated and irrigated wheat production. To compute overall average growth rate in the region, the following formulation is used:

$$\dot{P}\Big/P = s_u \left(\dot{Y}_u\Big/Y_u\right) + s_i \left(\dot{Y}_i\Big/Y_i\right) \qquad \ldots \qquad \ldots \qquad \ldots \qquad \ldots \qquad \ldots \qquad (9)$$

The left-hand side of this equation shows the overall wheat growth rate in the region. The first and the second terms on the right-hand side of the equation are growth rates of non-irrigated and irrigated wheat weighted by respective shares in total wheat production.

3. VARIABLE DEFINITIONS AND DATA

Time-series data for the period of 1970-71 to 1996-97 from four districts of the *barani* area of Punjab are used in this study. These districts are Attock, Rawalpindi, Jehlum, and Chakwal. Chakwal district was created in the early 1980s; however, the Bureau of Agricultural Statistics started reporting information about this district from the crop year 1984-85. Pooling the data from four of these districts resulted into an unbalanced panel consisting of 94 observations. The sources of data include various issues of Agricultural Statistics [Pakistan (Various Issues)] and Punjab Development Statistics [Punjab (Various Issues)].

The analysis of this study relies on a single-equation production function. The dependent variable is total wheat output in thousand maunds—non-irrigated or irrigated output. The input variables include total fertiliser used in nutrient tones,[6] area under wheat in thousand acres—irrigated and non-irrigated areas in respective equations. The third input used in the model is that of rainfall in millimetres: Since the study uses the aggregate production function, the rainfall variable is multiplied by the respective area under wheat to get availability of total quantum of rainfall in a particular crop season in *t*th year. In our opinion, if this adjustment is not made, the resulting parameter estimate of the area under wheat will be over- or under-estimated according to the impact of rainfall, which is expected to be positive in this study.[7]

4. EMPIRICAL RESULTS

Equation 1 is estimated using LIMDEP version 7 both for non-irrigated and irrigated wheat production functions and the results are reported in Table 1, which is the first step in the estimation of technical efficiency. The adjusted R^2 values of the models are 0.55 and 0.78, indicating 55 percent and 78 percent of the variations in the *barani* and irrigated wheat outputs, respectively, in the Pothwar area and are explained by the variables included in the production functions.

The coefficient for acreage in the *barani* equation is 0.5331, and is statistically significant at the 1 percent probability level—the magnitude of the coefficient implies an increase of about 5.3 percent in output by increasing the area under wheat by 10 percent, keeping all other inputs constant. On the other hand, the area coefficient in the irrigated equation is 0.9121, and is also statistically highly

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[6]Separate data regarding the use of fertiliser on non-irrigated and irrigated crops were not available. However, the farm level surveys indicate that the chemical fertiliser use on irrigated wheat crop is 100 percent higher than that of the use on the non-irrigated wheat farms [e.g., NFDC (1996)]. Consequently, to apportion the fertiliser use on the irrigated wheat acres (Ferti), the following formulation has been used:

Ferti = [(irrigated area * 2) / (irrigated area *2 + non-irrigated area)] * Total fertiliser use.

[7]Assume the following multiplicative aggregate production function:

$$Y = AX_1^{b1} X_2^{b2} X_3^{b3} X_4^{b4}$$

Multiplying the left-hand side of this equation with (X_4 /X_4) and the right-hand side with $(X_4/X_4)^{b1}$, $(X_4/X_4)^{b2}$ and $(X_4/X_4)^{b3}$ will yield :

$$(Y / X_4) = A(X_1 / X_4)^{b1}(X_2 / X_4)^{b2}(X_3 / X_4)X_4^{b1+b2+b3+b4-1=\theta}$$

It is clear from the above equation that even if the production function is based on per acre basis, the parameter estimates will remain the same as those of the aggregate. The only difference it makes is that of the estimate of the land variable. This coefficient (now θ) represents the returns to scale, ranging from –ive to +ive values: it exhibits decreasing, constant, or increasing returns to scales if θ is equal to 0, –ive, or +ive, respectively. If we go back to the original function but partially as

$$Y = AX_1^{b1} X_2^{b2}(X_3 / X_4)^{b3} X_4^{b3+b4}$$

then the parameter estimate of X_4 will be $b_3 + b_4$. Using this analogy, if rainfall is used as such, it will result in over-estimation of the parameter estimate of the land variable.

Table 1

Parameter Estimates of the Barani *and Irrigated Wheat Production Functions*

Variables	Barani Production Function		Irrigated Production Function	
	Coefficients	*t*-ratio	Coefficient	*t*-ratio
Constant	–0.4654	–1.323	–0.4435	–3.368
Area	0.5331[a]	4.805	0.9121[a]	13.775
Fertiliser	0.0378	0.965	0.0622[b]	2.047
Rain	0.2122[a]	4.372	0.0908[a]	2.96
Time	0.0289[a]	4.271	0.0304[a]	5.95
Adj. R^2	0.53		0.78	

Note: The data were tested for the auto-correlation problem: DW statistics were found very low—1.33 and
1.02 for the *barani* and irrigated equations, respectively—showing the problem of auto-correlation.
To correct this problem Cochrane-Orcutt procedure was used [Ramanathan (1992)]. The resulting
DW statistics, 1.78 and 1.86 for the respective equations, show no auto-correlation problem.
[a] Significant at 1 percent significance level; [b]significant at the 5 percent level of significance.

significant. The irrigated acreage coefficient shows almost 100 percent higher
response than that of the *barani* acreage. Its magnitude implies about 9 percent
increase in wheat output by increasing 10 percent wheat area under irrigation.

The coefficient of the fertiliser in *barani* equation is 0.0378, showing an
increase of about 3.8 percent in wheat output with 10 percent increase in the use of
fertiliser. However, the impact appears to be statistically non-significant. One of the
main reasons for this non-significant effect is the total dependence of fertiliser
applications and utilisation on the rain moisture, which is highly variable and
generally inadequate during the wheat crop season in *barani* areas of Punjab.[8]
Among the chemical fertilisers, nitrogen and phosphorus are the most commonly
used nutrients in wheat production. According to Khan (1985), the nitrogen is
chemically mobile in nature and becomes quickly available to the plants whether it is
applied at the time of seeding or is top-dressed at the tillering. However, its
utilisation totally relies on the soil moisture. On the other hand, phosphorous is
chemically immobile in nature and so gets fixed up in the soil complex and slowly
becomes available to the plants; its utilisation depends on the availability of rain
moisture at various stages of the plant growth. Consequently, the use of fertiliser in
barani wheat is not as effective as is under the irrigated conditions. It is clearly
evidenced by the fertiliser coefficient in the irrigated equation that is 0.0622, which
is not only double the size of the *barani* wheat equation but is also statistically
significant.

The coefficient of rainfall in *barani* wheat equation is 0.2122, indicating that
output increases by 2.1 percent with a 10 percent increase in rainfall and the impact

[8]New high-yielding varieties require about 16 inches delta of water, while the rainfall in *barani*
areas of Punjab ranges from a low of less than 4 inches in dry years to a maximum of 16 inches in the
wettest years during the wheat crop season.

is statistically highly significant. While the coefficient of rainfall in the irrigated equation is 0.0908: Although the impact is statistically significant, the magnitude of the coefficient is even less than half of its counterpart in the *barani* equation. This difference is justified on the grounds that the most of the plants' water requirement is being fulfilled by the assured water supply in irrigated fields; as a result, the marginal contribution of rainfall in irrigated wheat production is relatively less than that of in the *barani* case.

The coefficients for time in both the equations are statistically significant at the 1 percent significance level. The magnitude of the coefficient in the *barani* equation is 0.0289, showing an annual increase of about 2.9 percent in wheat output due to technological progress. While, the coefficient of time in irrigated equation is 0.0304, implying about 3 percent increase in output resulting from technological progress. The proximity of both of these parameter estimates shows that advancements in technologies for the region are equally accessible and adopted by the rainfed and irrigated farms. The technological change components in both the equations turned out to be very high. This has become possible probably due to higher use of tractor technology in the *barani* areas—which helps better levelling of the soil, timely conservation of rain moisture, uniform seeding, and timely sowing of the crop. According to Khan (1985), tractor cultivation in *barani* areas has shown an increase of up to 30 percent higher yield of wheat as compared to the traditional tillage with cow or donkey. Timely sowing of wheat crop greatly helps in achieving higher production potential: the research results show that the yield of wheat reduces up to 240 kg/ha for every 15 days delay in sowing after the optimum planting period of October 20 to November 20 in *barani* area [Khan (1985)]. Adoption of high-yielding, short-duration, and drought-resistant varieties was another crucial factor that has also substantially contributed to wheat output growth, since these varieties have the potential to use limited soil moisture more efficiently.[9]

Technical efficiency measures are obtained using Equations 4 and 5 and the results are given in Table 2. These results in the *barani* case show that the average efficiencies of districts Attock, Rawalpindi, Jehlum, and Chakwal, respectively, are 0.89, 0.84, 0.88, and 0.88; while the efficiency measures for the respective districts in the case of irrigated wheat are 0.89, 0.87, 0.89, and 0.90. The comparison of efficiency measures across the districts and between *barani* and irrigated cases shows that all the districts except Rawalpindi have achieved approximately the equal level of production potential. One of the main causes behind the Rawalpindi district to be technically less efficient could be that of its proximity to the bigger milk, meat, and vegetable markets in the twin cities. Since the wheat crop is

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[9]Continuous time series data for tractors and area under high-yielding varieties are not available. However, agricultural census and farm machinery census data indicate that there is about 5-fold increase (from 1975 to 1994) in farm tractors in the Pothwar region. The area under high-yielding varieties also increased by about 5 times during this period.

Table 2

Technical Efficiency Measures

Year	Technical Efficiency Non-irrigated					Technical Efficiency Irrigated				
	Attoc	Rpindi	Jehlu	Chakwa	Average	Attoc	Rpindi	Jehlu	Chakwa	Average
1972	0.73	0.65	0.72		0.70	0.80	0.74	0.78	0.77		0.77
1973	0.77	0.69	0.76		0.74	0.82	0.76	0.80	0.80		0.80
1974	0.81	0.72	0.80		0.77	0.85	0.79	0.83	0.82		0.82
1975	0.84	0.75	0.83		0.81	0.88	0.81	0.84	0.84		0.84
1976	0.87	0.77	0.86		0.84	0.90	0.83	0.86	0.86		0.86
1977	0.90	0.80	0.89		0.86	0.92	0.85	0.88	0.88		0.88
1978	0.92	0.83	0.92		0.89	0.93	0.87	0.90	0.90		0.90
1979	0.95	0.85	0.94		0.91	0.95	0.89	0.91	0.92		0.92
1980	0.96	0.87	0.96		0.93	0.96	0.90	0.92	0.93		0.93
1981	0.98	0.89	0.97		0.95	0.97	0.92	0.93	0.94		0.94
1982	0.99	0.90	0.98		0.96	0.97	0.93	0.94	0.95		0.95
1983	1.00	0.91	0.99		0.97	0.98	0.93	0.95	0.95		0.95
1984	1.00	0.92	0.99		0.97	0.98	0.94	0.95	0.95		0.95
1985	1.00	0.92	0.99		0.97	0.97	0.94	0.95	0.96		0.96
1986	0.99	0.93	0.98	0.86	0.94	0.96	0.94	0.95	0.96	1.00	0.96
1987	0.98	0.92	0.97	0.89	0.94	0.95	0.94	0.95	0.96	0.98	0.96
1988	0.97	0.92	0.95	0.91	0.94	0.94	0.94	0.95	0.95	0.97	0.95
1989	0.95	0.91	0.93	0.92	0.93	0.92	0.93	0.94	0.94	0.95	0.94
1990	0.93	0.90	0.91	0.92	0.91	0.91	0.92	0.94	0.92	0.93	0.92
1991	0.91	0.89	0.88	0.92	0.90	0.88	0.91	0.93	0.91	0.91	0.91
1992	0.88	0.87	0.85	0.91	0.88	0.86	0.89	0.92	0.89	0.90	0.89
1993	0.85	0.85	0.81	0.89	0.85	0.84	0.88	0.90	0.87	0.88	0.87
1994	0.82	0.83	0.78	0.87	0.82	0.81	0.86	0.89	0.85	0.85	0.85
1995	0.78	0.80	0.74	0.84	0.79	0.78	0.84	0.87	0.83	0.83	0.83
1996	0.75	0.77	0.70	0.81	0.76	0.75	0.82	0.85	0.81	0.81	0.81
1997	0.71	0.74	0.66	0.77	0.72	0.72	0.79	0.84	0.78	0.79	0.78
Average	0.89	0.84	0.88	0.88	0.87	0.89	0.87	0.90	0.89	0.90	0.89
Minimum	0.71	0.65	0.66	0.77	0.70	0.72	0.74	0.78	0.77	0.79	0.77
Maximum	1.00	0.93	0.99	0.92	0.97	0.98	0.94	0.95	0.96	1.00	0.96

relatively unprofitable as compared to raising livestock and growing vegetables, the farmers pay less attention to manage wheat farms.

The results given in Table 2 indicate that the average technical efficiency measures in the recent years ranges from 66 percent to 84 percent. This implies that wheat output could be increased by about 16 percent to 34 percent with the given technology and resource base. To exploit this production potential from the existing resources, the agricultural extension system has to play a greater role in assisting the

farming community in order to improve their management capabilities, so that they could adopt and use new technologies more effectively.

The results given in Table 2 also indicate that technical efficiency increased in all the districts up to the early 1980s, stagnated during the mid-1980s, and declined thereafter. However, the declining trend is observed in Chakwal district throughout the study period in the irrigated case; while, in the *barani* case, efficiency increased till 1992 and declined thereafter.

For the purpose of output growth decomposition, Equation 8 has been used and the results for *barani* wheat are reported in Table 3, while the results for the irrigated case are presented in Table 4. The results for *barani* wheat show that during the study period wheat output increased at an annual growth rate of 2.71 percent. Technological change turned out to be the major source behind this growth, i.e., 2.89 percent. The share of inputs in this annual increase is negative –0.28 percent, while the technical efficiency contribution to the overall growth in wheat output is observed to be 0.10 percent per annum. In spite of higher technological change, the negative trends in efficiency in recent years, as could be seen from the table, resulted in negative productivity growth, which is the sum of technological progress and growth in technical efficiency.

The negative rate of *barani* wheat output growth that stems from the changing inputs (–0.28 percent) is further decomposed into its constituent factors that are fertiliser, rains, and area under wheat. The results given in Table 3 indicate that the fertiliser contribution is 0.47 percent and the favourable rains share growth in output at about 0.32 percent; while, the area under *barani* wheat is declining over time and thus pushing the rate of growth in output by a significant amount, measuring –0.87 percent per annum—resulting in net input effect to be negative.

The results also show that the total *barani* wheat output increased by about 70 percent during the study period. Of this total growth, 75 percent and 3 percent are attributable to technological change and improvement in technical efficiency, respectively. While, inputs contributed negatively to output growth. These figures again witness that technological change has been the main source of increase in total *barani* wheat output in the Pothwar region.

On the other hand, the results given in Table 4 show that the irrigated output increased at the faster rate, that is, of 4.70 percent per annum. Again, the technological progress is the main driving force, i.e., 65 percent, inputs effect stands second by contributing about 34 percent, and improvement in technical efficiency stands at the third place, with a contribution of only 1.28 percent. However, the results in irrigated wheat also show that the change in technical efficiency has turned into a negative trend from a +3.24 percent in 1972-73 to –3.01 percent in 1996-97. This implies that, despite high technological progress, productivity growth has become almost zero in the recent years. As regards the contributing factors to the inputs component of the growth (i.e., 1.6 percent), the increase in irrigated area

Table 3

Wheat Output Growth Decomposition in Barani *Area*

Year	Output Growth Decomposition				Input Growth Decomposition		
	Total Growth	Technolo Change	T.Effici Change	Inputs Changes	Change Area	Change Fertiliser	Change Rain
1973	23.47	2.89	4.94	15.64	2.80	1.10	11.74
1974	−16.19	2.89	4.53	−23.61	−0.96	−1.21	−21.44
1975	21.12	2.89	4.12	14.11	0.40	0.21	13.50
1976	14.25	2.89	3.71	7.65	−0.18	2.18	5.65
1977	−27.12	2.89	3.30	−33.30	−0.60	0.60	−33.30
1978	28.00	2.89	2.88	22.22	1.92	−1.11	21.42
1979	12.16	2.89	2.47	6.79	0.00	1.84	4.96
1980	13.68	2.89	2.06	8.73	0.26	1.04	7.43
1981	6.93	2.89	1.65	2.39	−0.88	−0.56	3.83
1982	1.88	2.89	1.24	−2.25	1.13	0.54	−3.92
1983	6.86	2.89	0.83	3.14	0.13	−0.03	3.04
1984	−21.63	2.89	0.42	−24.94	−5.26	0.94	−20.62
1985	−14.71	2.89	0.01	−17.61	−18.65	−0.77	1.80
1986	15.12	2.89	−3.08	15.31	1.81	0.66	12.83
1987	−0.99	2.89	0.04	−3.91	1.64	0.99	−6.55
1988	−11.73	2.89	−0.44	−14.19	−13.03	−0.73	−0.43
1989	4.80	2.89	−0.92	2.83	9.30	−0.01	−6.46
1990	10.70	2.89	−1.41	9.21	−0.90	0.37	9.74
1991	4.98	2.89	−1.90	3.99	0.76	−0.61	3.84
1992	−2.16	2.89	−2.39	−2.66	−0.42	0.81	−3.05
1993	0.87	2.89	−2.89	0.87	2.60	0.92	−2.65
1994	−21.16	2.89	−3.39	−20.66	−5.46	−0.64	−14.56
1995	14.82	2.89	−3.89	15.82	2.10	−0.86	14.58
1996	2.46	2.89	−4.40	3.97	0.54	0.86	2.56
1997	−15.58	2.89	−4.90	−13.57	0.35	−1.10	−12.82
Annual	2.71	2.89	0.10	−0.28	−0.87	0.27	0.32
(%)	(100)	(106.64)	(3.69)	(−10.33)			
Total	70.35	75.14	2.57	−7.36	−22.65	6.98	8.31
(%)	(100)	(106.81)	(3.65)	(−10.46)			

Table 4

Wheat Output Growth Due to Irrigation

Year	Output Growth Decomposition				Input Growth Decomposition		
	Total Growth	Technolo Change	T.Effici Change	Inputs Changes	Change Area	Change Fertiliser	Change Rain
1973	31.75	3.04	3.24	25.47	15.85	3.09	6.54
1974	–0.66	3.04	2.98	–6.68	3.61	–2.00	–8.29
1975	–5.27	3.04	2.71	–11.02	–15.58	–0.03	4.59
1976	28.48	3.04	2.44	23.00	14.57	4.66	3.76
1977	–13.37	3.04	2.18	–18.59	–5.11	1.44	–14.92
1978	29.50	3.04	1.91	24.55	16.24	–2.78	11.09
1979	9.68	3.04	1.64	5.00	0.00	3.23	1.76
1980	–3.87	3.04	1.38	–8.29	–10.04	0.41	1.34
1981	1.82	3.04	1.11	–2.33	–2.62	–1.03	1.32
1982	3.32	3.04	0.84	–0.56	–0.59	0.99	–0.96
1983	7.00	3.04	0.58	3.38	1.15	0.43	1.80
1984	8.70	3.04	0.31	5.35	10.60	2.59	–7.83
1985	–22.28	3.04	0.04	–25.36	–26.66	–0.69	1.99
1986	29.21	3.04	1.00	25.17	14.22	1.35	9.60
1987	–7.00	3.04	–0.76	–9.28	–5.57	0.79	–4.50
1988	–4.83	3.04	–0.99	–6.89	–5.28	–1.39	–0.21
1989	10.79	3.04	–1.21	8.96	12.04	0.26	–3.34
1990	13.35	3.04	–1.44	11.74	4.31	0.72	6.72
1991	–2.78	3.04	–1.66	–4.15	–5.18	–0.66	1.69
1992	–3.34	3.04	–1.89	–4.49	–4.14	0.62	–0.98
1993	7.64	3.04	–2.12	6.72	7.94	1.39	–2.62
1994	–15.23	3.04	–2.34	–15.93	–7.37	–0.22	–8.34
1995	9.95	3.04	–2.57	9.47	2.71	–2.01	8.78
1996	4.99	3.04	–2.79	4.74	2.39	1.65	0.70
1997	–7.18	3.04	–3.01	–7.21	2.61	–1.66	–8.16
Annual	4.70	3.04	0.06	1.60	0.77	0.49	0.34
(%)	(100)	(64.68)	(1.28)	(34.04)			
Total	122.26	79.04	1.59	41.62	20.11	12.72	8.79
(%)	(100)	(64.65)	(1.30)	(34.04)			

under wheat shares about 0.77 percent; 0.49 percent is attributable to growth in fertiliser use and 0.34 percent is shared by favourable rains.

Overall growth in wheat output in the region is also calculated using Equation 9 and the results are reported in Table 5. The results show that total wheat output in the region increased at an annual rate of about 2.97 percent—84 percent (i.e., 2.49) of this growth is shared by the growth in *barani* wheat production and only 16 percent is attributable to improvement in irrigated wheat output.

Table 5

Weighted Average Growth Rates

Year	Irrigated Growth	*Barani* Growth	Average Growth
1973	–0.06	21.46	21.40
1974	–0.50	–14.66	–15.16
1975	2.23	19.46	21.70
1976	–1.59	12.56	10.97
1977	3.87	–23.56	–19.69
1978	1.28	24.30	25.58
1979	–0.41	10.85	10.44
1980	0.17	12.37	12.54
1981	0.32	6.26	6.58
1982	0.73	1.68	2.41
1983	0.82	6.21	7.03
1984	–2.49	–19.21	–21.71
1985	3.53	–12.94	–9.41
1986	–0.84	13.31	12.48
1987	–0.45	–0.90	–1.34
1988	1.00	–10.65	–9.65
1989	1.98	4.09	6.07
1990	–0.41	9.10	8.68
1991	–0.44	4.33	3.89
1992	1.02	–1.87	–0.85
1993	–2.17	0.74	–1.43
1994	1.59	–17.77	–16.18
1995	0.64	12.92	13.56
1996	–0.80	2.19	1.39
1997	0.66	–13.40	–12.75
Average	0.48	2.49	2.97
(%)	(16.16)	(83.84)	(100)

The results discussed above indicate that both *barani* and irrigated production growth analyses show almost similar trends. There are various reasons for the negative trends in efficiency in the region and the total area under wheat in general and under *barani* wheat in particular.[10] The first reason could be that of relative unprofitability of the crop concerned as compared to other enterprises. Besides, the published sources of data and the market trends show that a significant amount of area in the *rabi* season is being diverted towards growing more vegetables and irrigated wheat, which has become possible due to the increased availability of

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[10]Irrigated area shows an increasing trend. However, the irrigated wheat area is only 6 percent of the total wheat area and, consequently, this increase is less than the decline in area under *barani* wheat.

underground water in the Pothwar region. We are also of the opinion that due to rapid urbanisation and, consequently, higher demand for meat and milk, the farmers in the Pothwar area grow more fodder crops that require a higher quantity of water.[11] The second reason that could be considered for this trend is that due to small farm size and risky climatic conditions, most of the farming in the Pothwar region is part-time [Khan *et al.* (1990)], which might lead to lower productive efficiency.

The rapid advancements in biological, chemical, and mechanical technologies themselves could be a third important cause of this declining trend in efficiency. New technologies are becoming increasingly complex and require exploration, experimentation, education and frequent training, regular contact within the farming community, and an effective flow of technical information [Lall (1993)]. Such activities and links are considered to be deficient for the agriculture sector as a whole [Azhar (1993)], and, thus, the *barani* area is no exception. Moreover, during the periods of rapid scientific advancements, the administrators (farmers) are required to strengthen their management capabilities and skills so as to adopt and use complex technologies more rationally even to keep the productive efficiency at the static level [Lall (1993)].

5. CONCLUSION AND POLICY IMPLICATIONS

The main objective of the study is to disintegrate the sources of wheat output growth in the *barani* area of the Punjab. At presently, about 7 percent of the wheat area in Pothwar is under well irrigation and, thus, a similar analysis is also conducted to compute irrigated wheat share in the overall growth of the region. Overall wheat output grew by 2.97 percent per annum, of which 84 percent was attributable to the growth in *barani* wheat and the remaining 16 percent was shared by the irrigated output.

The results show that the major driving growth factor was technological change under both conditions, which contributed about 107 percent of the total change in *barani* output and about 65 percent in irrigated output. The change in efficiency and inputs, respectively, contributed about 3.7 percent and –10.3 percent in *barani* and 1.3 percent and 34 percent in irrigated wheat.

The results further revealed that the reduction in system efficiency caused productivity growth to decline over the period of study: annual growth in productivity decreased from almost +8 percent to –2 percent under *barani* conditions and from 6.3 percent to zero percent under the irrigated system during the study period. The effects of reduction in area under *barani* wheat were greater than the positive effects of fertiliser and rainfall in *barani* conditions causing the net output effect attributable to inputs to be negative (i.e., –0.28 percent). While the input effect under irrigated conditions was positive (1.6 percent); of which, 0.77 percent, 0.49 percent, and 0.34 percent were attributable to marginal increase under irrigated area, higher use of fertiliser, and favourable rains, respectively.

[11]The data regarding the *rabi* fodder in Pothwar area are not available from any published source.

Profitability analysis of various agricultural enterprises was not the objective of the paper. However, we speculate that the main reason for the reduction in area under wheat is its low relative profitability as compared to growing vegetables and raising livestock. The same reason could also be a source of declining efficiency. Moreover, under rapid technological advancements, the farmers and the administrators need to be educated and trained along with a more effective flow of information to maintain efficiency even at the same level [Lall (1993)]. These results lead us to conclude that the agricultural extension system in its linkages with the research departments has to play a greater and effective role in assisting the farming community of the *barani* areas to improve their managerial potential, so that they could adopt and use new technologies more rationally.

Furthermore, there is a dire need to increase the water use efficiency in the rainfed areas, since the performance of farming relies on seasonal rains: good rain results in higher output and poor rains lead to poor crops. Moreover, the ensured supply of other inputs along with reasonable input-output price structure is also essential to curb the downward trend in area under wheat.

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