The Pakistan Development Review
40 : 1 (Spring 2001) pp. 1–25

Agricultural Productivity Growth Differential in Punjab, Pakistan: A District-level Analysis

MUNIR AHMAD

The results of this paper show that the crop output increased at the rate of 2.6 percent per annum, dominated by the share of TFP growth. Wide variation exists among cropping systems as well as within the system both in TFP growth and output growth. The *mungbean* zone emerged as a leader in TFP growth with 3.6 percent per annum, followed by *barani* (3.2 percent), *cotton* (1.9 percent), *mixed* (1.1 percent), and *rice* (1.0 percent) zones. Rice, mixed, and cotton zones show a negative trend in efficiency, and the respective causes appear to be the dominant factor of land degradation sourced by the existence of nutrient-exhaustive cropping pattern, increasing problem of waterlogging and salinity, and the use of brackish underground water, plus the prevalence of curl leaf virus disease in the cotton zone during the 1990s. The other reasons could be the low literacy rate among the farmers in most of the districts of the latter two cropping systems. Besides, the majority of them are also characterised as having very low status in development ranking. The data also show that the area under rice and sugarcane, a highly water-intensive crop, had increased in most of the districts of mixed and cotton zones, during the 1990s instrumented by high instability in cotton output growth as compared to rice and sugarcane. The sources of instability include high volatility in prices, vulnerability of the crop to disease and insect attack, consistently rising production cost, incapacity of the farming communities to deal with the dynamism of technology in cotton production, and increasing waterlogging and salinity problem.

1. INTRODUCTION

Prior to Independence, the united Punjab was considered to be the granary of India in terms of its contributions towards food and fibre basket. It was made possible by the huge investment undertaken by the then colonial government in irrigation canal network to exploit the maximum potential of the most fertile lands of the country. At the time of Independence, Pakistani Punjab got control of 62 percent of the area of the United Province and 70 percent of the fertile canal-irrigated tracts [Randhawa (1954) cited in Ahmad and Choudhry (1997)].

Munir Ahmad is Senior Research Economist at the Pakistan Institute of Development Economics, Islamabad.

Author's Note: I would like to thank Akhtiar Hussain Shah and Syed Abdul Majid of the Pakistan Institute of Development Economics for collection of data. I am also grateful to Drs A. R. Kemal and M. Ghaffar Chaudhry, Director and Joint Director of PIDE respectively, to Professor Bashir Ahmad of the University of Agriculture, Faisalabad, and to Dr Abdul Salam, Member of the Agricultural Prices Commission, Islamabad for their comments on an earlier draft of this paper.

At present, Punjab hosts 56 percent of the total population while sharing 26 percent of the total area of the country. Out of this provincial geographical area, over 60 percent is under cultivation, which comes to about 56 percent of the county's total cultivated area. The province of Punjab uses agricultural lands relatively more intensively and thus shares 70 percent of the total area under all crops in the country. As such, it contributes significantly to the pooled agricultural output in the country—sharing more than 70 percent of the cereal, around 60 percent each of the sugarcane, oilseeds, and fruit, and nearly 80 percent each of the cotton, pulses, and vegetables output. On this account, the Province of Punjab continues to be the most agriculturally well-off area, playing a leading role in the agricultural development of the country. Endowed with a well-knit irrigation system, and substantial private and public investment in water-related projects to expand the irrigation capacity thereafter, the agriculture sector has grown progressively well despite poor supporting institutional structure and the lack of trained scientific manpower. It is expected that national dependence on Punjab for food and fibre is likely to increase with the rapidly growing population of the country which calls for a high sustainable growth in the agriculture sector.[1]

In the past, growth in output came from more intensive use of land, greater water availability both from surface and underground resources, and chemical, mechanical, and biological technologies introduced during the mid-1960s, with steady support of the local research institutions in developing new technologies and production techniques. Nonetheless, most of these efforts remained concentrated on major crops, particularly wheat and cotton—50 to 60 new varieties each of these two crops have been released for farm-level adoption in the last two decades. Moreover, agricultural extension, education, credit, and investment in rural infrastructure have also played their role in realising greater potential of the sector through increasing management efficiencies of the farming communities [Ali and Flin (1989); Parikh, Ali and Shah (1995); Battese, Malik and Gill (1996)]. However, chances of expansion in two of the major factors of production (i.e., irrigation water and cultivated lands) are too slim. Both of these critical inputs face declining trends in quantitative as well as qualitative terms due to waterlogging and salinity, mining of the nutrients from the soil in the absence of proper and balanced doses of organic and inorganic fertilisers, and the lack of new water storage reservoirs. The problem of soil degradation is said to be more prominent in the wheat-rice belt, causing yields to stagnate or even fall off because of continued cereal mono-cropping for long [Byerlee and Siddiq (1994); Hobbs and Morris (1996)], and thus the sustainability of the system has become a serious issue.

[1]There is no denying the fact that agricultural development efforts in the country need a balanced approach in all provinces in order to exploit untapped productive resources and allocate them to enhance the country's output and reduce poverty. Nonetheless, any positive or negative impact of national policy or nature on the fate of agriculture could evidently be felt in the national pool through the Punjab's share. Consequently, it is worthwhile to study the performance of Punjab's agricultural sector although it may not be true for the country as a whole, as it can still highlight some insights about it.

Recently, Ali and Byerlee (2000), researching on resource degradation issue, found negative productivity growth in the rice-wheat system, but observed positive trends in other irrigated cropping systems of Punjab. However, a conscientious look at the results reveals that the conclusion of the study based exclusively on the negative growth rate in rice-wheat system is not plausibly supported by figures reported for different periods, for instance –2.43 percent, –0.60, and 0.88 per annum during 1966–74, 1975–84, and 1985–94, respectively. These growth rates undoubtedly show a consistent improvement in productivity over time.[2] Moreover, the study does not provide district-level results, and hence the productivity growth distress portrayed by the study does not depict the true picture. The results of our study illuminate the existence of wide variation in productivity growth at the districts level in various cropping systems. The results of this study indicate positive total factor productivity (TFP) growth rate in the rice-wheat system during the 1990s that goes well with the growth rate found by Ali and Byerlee for the period of 1985–94.

The analysis of past performance of the agriculture sector at the disaggregated level (district level), a major objective of this study, is crucial to embark on targeted policy actions for improving the future performance of this sector.

The sources of performance of the agriculture sector can be categorised into two major components [Nishimizu and Page (1982); Srinivasan (2001)]: (1) the growth in factors of production—this pertains to the economies of size and indicates the movement of the producer along the best practice production frontier; and (2) productivity growth that refers to shifting of the production frontier upwards in case of progress, and downwards as a result of regress. Productivity growth can be further decomposed into two components, which are (i) innovations that create new and/or improved inputs and techniques of production and new uses for existing products, which is simply denoted as 'technological change' in the literature; and (ii) growth in the efficiency of the use of these technologies. The latter requires technological capability like technical, managerial, and institutional skills, and building such capabilities in harmony with the dynamism of changing technologies. Embodying the state of disequilibria involves constant interaction among members of the farming community, effective and continuous flow of information, timely and

[2]The study also shows that the use of inputs per hectare faces a declining trend except for fertiliser and machinery. It further shows positive productivity growth rates in other systems: 0.87 percent, 1.57 percent, and 1.32 percent in wheat-mix, wheat-cotton, and wheat-mungbean, respectively, with 1.26 percent per annum for overall Punjab ranging from 0.5 percent during 1966-74 to 1.6 percent during 1985-94. This study uses district-level data and applies a dual cost function. There seems to be some procedural problems in the estimation of the function. Another provincial level study, by Rosegrant and Evenson (1993), found productivity growth rates of 1.42 percent, 2.13 percent, and –0.84 per annum for the periods of 1956-65, 1965-75, and 1975-85, respectively, for Punjab. Ali (2000) finds productivity growth rates of 2.8 percent, 1.2 percent, 2.6 percent, and 2.2 percent per annum during the periods of 1960-70, 1971-80, 1981-90, and 1991-96, respectively, for Pakistan, using aggregated data.

dispensing support of the institutions like agricultural extension, education, and finance, well-established input and output market network, healthy physical infrastructure, etc. [Kalirajan (1991); Lall (1993)].

This paper has been organised in the following four sections. The preceding Section 1 introduces the issues to be discussed in the correct study. Section 2 presents the methodological framework. Section 3 gives the data and explanation of variables and the empirical model. Section 4 discusses results. The concluding remarks are given in Section 5.

2. METHODOLOGICAL FRAMEWORK

The prime objective of this study is to decompose output growth into total factor productivity and growth in inputs. The first component consists of two parts, which are technological change and changes in technical efficiency. Before presenting the statistical model used in the decomposition analysis, a simple graphical explanation based on a frontier production 'or a best practice' function is given as follows.

2.1. Output Growth Decomposition: A Graphical Representation

A frontier function represents an outer boundary of physical input-output combinations and any firm producing at the frontier realises full potential of the available technology and is 100 percent efficient. Assuming Cobb-Douglas production technology and neutral technological change, production performance over time is depicted in Figure 1, where Ft_1 and Ft_2 represent production frontiers in periods 1 and 2, respectively. While, At_1 is the average production function in period 1; the curve for the average production in period two is not drawn; however, it passes through point G. Points A and G are observed levels of output with their associated potential output levels at D and H in periods 1 and 2, respectively. The vertical distance between observed and potential levels of output, showing a shortfall of observed output from the maximum achievable output, measures the technical inefficiency of the firm/producer. Point C indicates the expected output level in case of increase in the inputs bundle from X_1 in period 1 to X_2 in period 2, assuming no change in efficiency, while its associated potential output is F. Had the producer realised the maximum achievable potential output, i.e., D in period 1, then the anticipated output in period 2 would have been F and consequently the additional output due to higher use of inputs would have been EF.

The shift in frontier production function from Ft_1 in period 1 to Ft_2 in period 2 is termed as technical change, which is equal to the vertical distance FH [Nishimizu and Page (1982)]. Adding to this value (i.e., distance FH), the increase in output attributable to higher use of inputs (EF) sums to only BE″, which is less than the actual increase in output from period 1 to 2, i.e., BG, by the distance E"G. This difference is explained by the improvement in technical efficiency—the ability of the producer to achieve higher output by moving closer to the frontier. Based on this interpretation, the increase in output from B (Y_1) in period 1 to G (Y_2) in period 2 can be decomposed as

$$\Delta Y = Y_2 - Y_1 = \Delta X_Y + \Delta T_Y + \Delta TE_Y \quad \ldots \quad \ldots \quad \ldots \quad \ldots \qquad (1)$$

Where, ΔY = change in total output that is from B in period 1 to G in period 2;

ΔX_Y = change in output attributable to increase in inputs, which is equal to the distance CB;

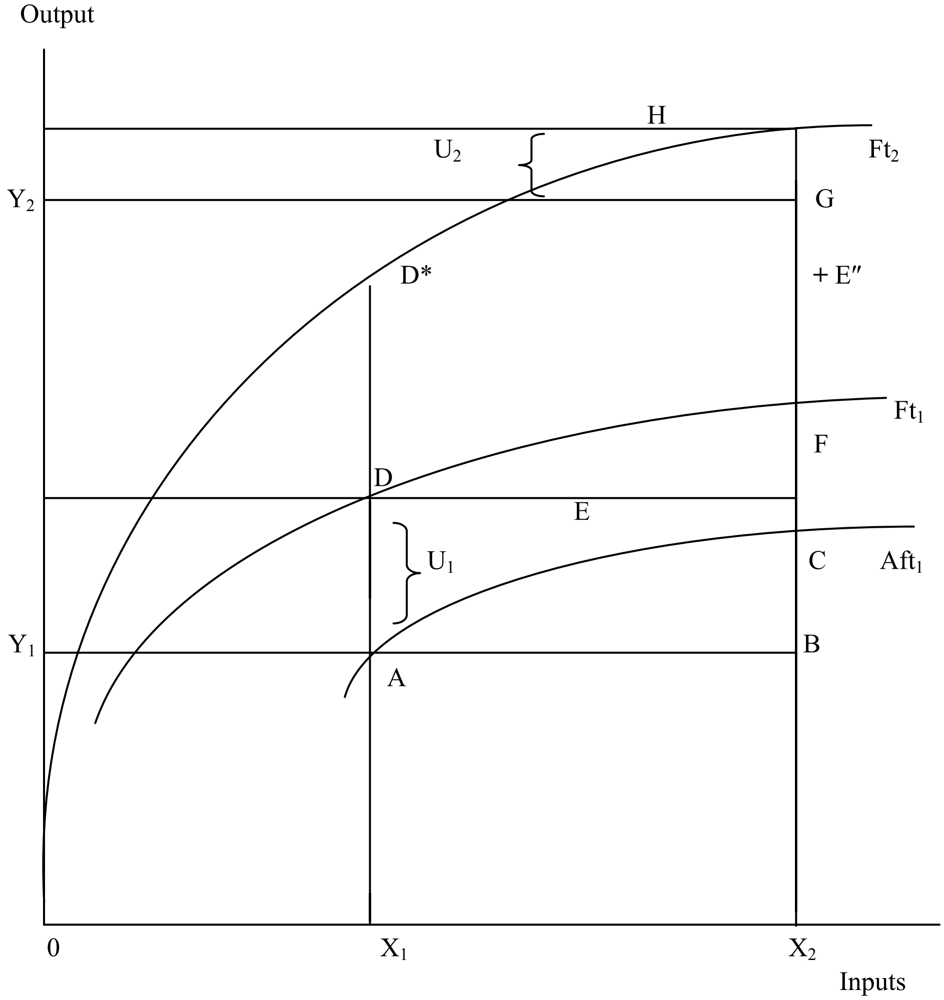

Fig 1. A Graphical Representation of Output and TFP Growth.

ΔT_Y = increase in output due to technological change measured by the vertical distance in between two frontier curves at a given level of output, i.e., FH; and

ΔTE_Y = gain in output due to improvement in technical efficiency, U_1-U_2.

Given the above exposition, the growth in Total Factor Productivity (TFP) can be obtained as

$$\Delta TFP = (H–F) + \{(D–A) –(H–G)\} \qquad \dots \quad \dots \quad \dots \quad \dots \qquad (2)$$

2.2. Statistical Model

In statistical notations the frontier production function can be expressed as [Fecher and Pestieau (1993)]:

$$Y_{it} = f[X_{it}, t]\, e^{uit}\, e^{vit} \qquad \dots \quad \dots \quad \dots \quad \dots \quad \dots \qquad (3)$$

where i denotes the ith production unit [here district], t is time; Y_{it} represents the observed output, and X_{it} is vector of inputs; e^{uit} refers to Technical Efficiency (TE) of production; and e^{vit} stands for the usual random error term representing factors not under the control of the producer, and assumes normal distribution with zero mean and constant variance. The derivative with respect to time of a log version of Equation 3 yields

$$Y^{\bullet}_{it}/Y_{it} = f_x(X^{\bullet}_{it}/X_{it}) + f_t + u^{\bullet}_{it} \qquad \dots \quad \dots \quad \dots \quad \dots \qquad (4)$$

where the dots symbolise time derivative, $f_x(X^{\bullet}_{it}/X_{it})$ represents the growth in inputs weighted by the respective elasticity coefficients, f_t is output elasticity with respect to time t representing the technological change, and the last term indicates the change in technical efficiency. The gain in output, which is not explained by the variations in inputs, is regarded as the contribution of growth in TFP that combines the effects of technological change at the frontier and the changes in technical efficiency at the production unit [Fecher and Pestieau (1993)]. The TFP growth can thus be obtained using Equations 2 and 4 as follows:

$$\Delta TFP_{it} = f_t + u^{\bullet}_{it} \quad \dots \quad \dots \quad \dots \quad \dots \quad \dots \quad \dots \qquad (5)$$

To measure the productivity growth for ith district at time t, we adopt a two-step procedure suggested by Cornwell, Schmidt, and Sickles (1990). In the first step, Equation 3 can be estimated using an appropriate functional form. A variety of methodologies have been used in the literature to parametrically estimate the frontier functions using observed data to construct the frontier. Given the panel nature of data at hand we would estimate the Fixed Effects (FE), Random Effects (RE), and the Ordinary Least Squares (OLS) versions and finally use the results of a preferred model for further analysis based on specification tests.[3] To proceed with this step and assuming a Cobb-Douglas functional form, Equation 3 is expressed as

$$lnY_{it} = \alpha + \sum_k \beta_k lnX_{kit} + \delta T + u_{it} + v_{it} \quad \dots \quad \dots \quad \dots \quad \dots \qquad (6)$$

where, T represents time index, a proxy for technological change, and β and δ are unknown parameters to be estimated, and *ln* denotes natural log. The technical efficiency component can be allowed to vary over time by replacing u_{it} with an expression "$\gamma_i + \lambda_i T + \theta_i T^2$"; where, γ_i relates to district-specific, and λ_i and θ_i are other district-specific parameters relating to time and time squared.

In the second step, the estimates of γ_i, λ_i, and θ_i can be obtained by regressing the residuals, $\varepsilon_{it,}$ from the first step—Equation 6, including the districts effects as well as the usual error term using OLS. The second step equation can be written as

$$\hat{\varepsilon}_{it} = \gamma_i + \lambda_i T + \theta_i T^2 + v_{it} \quad \dots \quad \dots \quad \dots \quad \dots \quad \dots \qquad (7)$$

where v_{it} is i.i.d $N(0, \sigma^2_v)$. The fitted values from Equation 7 ($\hat{u}_{it}$) can be used for the technical efficiency calculations at each observation as follows:

$$TE_{it} = exp(\hat{u}_{it} - \hat{u}_{max}) \quad \dots \quad \dots \quad \dots \quad \dots \quad \dots \qquad (8)$$

Where $\hat{u}_{max}$ indicates the most efficient observation in the panel. The values of *TE* ranges between zero and one ($0 \leq TE \leq 1$)—the closer the value to one, the greater is the level of efficiency of a production unit, and vice versa. The total factor productivity growth measures can thus be obtained by combining the technological change component, i.e., δ, from Equation 6, and the result from differentiating Equation 7 with respect to time. This can be expressed as

$$\Delta TFP = \delta + \lambda_i + 2\theta_i T \quad \dots \quad \dots \quad \dots \quad \dots \quad \dots \qquad (9)$$

[3]Two specification tests will be conducted in order to have a preferred model for further analysis from among the OLS, RE, and FE. The first relates to the FE model testing whether the district effects are zero, which can be tested using *F*- test, which is written as: $F[J, NT\text{-}K]=\{(SSE_R\text{-}SSE_{UR})/J\}/\{SSE_{UR}/(NT\text{-}K)\}$, SSE is error sum of squares, R and UR represent restricted and unrestricted models, and J, NT, and K are number of restrictions, number of observations, and the parameters to be estimated in the UR model. The second is the Hausman specification test (HM), which is used to test the null hypothesis, H_0: $E(X'\varepsilon)=0$ against the alternate hypothesis, H_A: $E(X'\varepsilon)\neq 0$ [Kmenta (1986)]. Under the H_0 the parameters of the RE effect model should be significantly different from the parameters of the FE model. The significant difference between these two estimators indicates the presence of a significant association between the firm (district) effects and the other variables in the model. If β^{FE} denotes the vector of FE estimators and β^{RE} the vector of RE estimators, then the HM can be written as: $HM=(\beta^{FE} - \beta^{RE})' [Var(\beta^{FE}) - Var(\beta^{RE})]^{-1} (\beta^{FE} - \beta^{RE})$. The statistic HM has an asymptotic chi-square, χ^2, with degrees of freedom equal to the slope parameters used in the HM test. If HM > χ^2 value then H_0 is rejected in favour of H_A implying that the RE specification is misspecified and the preferred specification is FE.

3. DATA, VARIABLES, AND EMPIRICAL MODEL

3.1. Data and Variable

The study uses district-level data of 34 districts of Punjab covering 1991-92 to 1998-99 period—the data from two of the new districts were combined with the respective districts from which these were separated in early 1990s because of some data limitations. From among the remaining 32, 3 districts had T–1 observations. Thus the panel is unbalanced. Production data regarding 27 crops is aggregated using 1990-91 prices. The input variables include total fertiliser used in nutrient tonnes, total irrigated cropped area in acres, aggregate non-irrigated cropped area—to allow difference in quality of land and also the contribution of irrigation water, and total annual rainfall in millimetres.[4] To use the latter as an independent variable in the aggregate production function, it is multiplied by the total cropped area of the respective district to allow the availability of total quantum of rainwater in *t*th year and *i*th district [for detailed argument see Ahmad and Ahmad (1998)].[5]

Two additional variables are also constructed which relate to short-term and long-term credit disbursed by the Agricultural Development Bank of Pakistan (ADBP) at the district level, and the data for these variables were obtained from the ADBP headquarters at Islamabad.[6] The inclusion of credit as an independent variable in the production function is usually criticised on the grounds that it does not affect the output directly; rather it has an indirect effect of output through easing the financial constraints of the producer in order to purchase inputs. However, we have included these variables in the production function based on a detailed argument of Carter (1989). He argues that credit affects the performance of the agriculture sector in three ways: (1) it encourages efficient resource allocation by overcoming financial constraints to purchase inputs and use them optimally—"….this sort of effect would shift the farmer along a given production surface to a more intensive, and more remunerative, input combination" (p.19); (2) if the agricultural credit is used to buy a new package of technology, say high-yielding seed and other unaffordable expensive inputs, it would help farmers to move not only closer to the production frontier but also

[4]Agricultural labour is another important input; however, the district-level data for labour is not available. Ali and Byerlee (2000) show that the average labour use per hectare for crops has declined in the post-Green Revolution period. This demonstrates that partial productivity for agricultural labour has increased over time, indicating that the results of this study, to some extent, could be downwards-biased.

[5]Source of these data include various issues of Agricultural Statistics [Pakistan (Various Issues)], Punjab Development Statistics [Punjab (Various Issues)], and records of the Ministry of Food, Agriculture, and Livestock, Government of Pakistan.

[6]Among the institutional sources, the Agricultural Development Bank of Pakistan provides about 70 percent of the agricultural credit in Pakistan. The bank provides short-term, medium-term, and long-term loans. The former are usually production loans, while the other two are development loans. Production loans are short-term loans which are used for the purchase of seed, fertiliser, pesticides, labour hiring, etc.; and development loans pertain to the purchase of farm machinery, tubewells, land development, etc.

shift the entire input-output surface—in this regard it embodies technological change and a tendency to increase technical efficiency of the farmers; and (3) credit can also increase the use intensity of fixed inputs like land, family labour, and management, persuaded by the 'nutrition-productivity link of credit'—that raises family consumption and productivity. Carter's reasoning implies that agricultural credit not only increases management efficiency but also affects the resource allocation and farm profitability favourably. However, the reliable time series district-level data regarding seed, pesticides, labour hiring, farm machinery, etc., are not available. Nonetheless, both of the credit variables, short-term and long-term, are adjusted by the GDP deflator to account for inflationary prices.

To capture district-specific effects like soil quality, infrastructure, water quality, farm size, cropping intensity, educational status of the farming community, and management efficiency, district dummies have been used in the model estimation.[7] The effects of these variables on agricultural productivity, however, may not be constant over time. The econometric model used in this study allows this variation as explained in the previous section.

3.2. Empirical Model

Assuming the production technology to be of the Cobb-Douglas form and the district effects varying over time, the production frontier can be expressed as

$$lnY_{it} = \alpha + \beta_1 D_{un} + \beta_2\, ln(UNIRR_{it}) + \beta_3\, ln(IRRA_{it}) + \beta_4\, ln(FERT_{it}) + \beta_5\, ln(RAINA_{it}) + \beta_6\, ln(SLOAN_{it}) + \beta_7\, ln(LLOAN_{it-1}) + \delta T + \varepsilon_{it} \quad \ldots \quad (10)$$

and $\hat{\varepsilon}_{it} = \sum_i \gamma_i Di + \sum_i \lambda D_i T + v_{it}$

where:

D_{un} is a dummy variable assuming value of One when the *i*th district at the *t*th time period has zero non-irrigated area, otherwise 0;[8]

[7]Time-series district-level data regarding farm size, cropping intensity, and level of farmers' education are not available. These variables, however, affect the performance of agriculture in different ways: farm size is expected to have a negative association with output per unit of land [Chaudhry *et al.* (1985)]; small farms are negatively associated with the level of technical efficiency [Ahmad and Qureshi (1999)]; educational attainment has a positive impact on the level of efficiency [Ali and Flinn (1989); Parikh and Shah (1994)]. The literacy rate among male population (aging 10 years and above) in the rural areas is taken as the educational status of the farm managers. The data regarding these variables for a single period can be obtained from the 1990 Census of Agriculture and 1998 Census of Population (Appendix Table A). These data will be used in the results and the discussion section to compare the productivity performance of various districts as well as the cropping systems.

[8]There are 13 observations in the data where non-irrigated area is zero. To account for zero observations in the Cobb-Douglas functional form, the following procedure is adopted: in Equation 10, the UNIRR variable is transformed into log form when UNIRR>0, while zero's are taken as such, and an additional variable is D_{un} is created assuming value of 1 when the UNIRR is equal to zero and takes zero value if the UNIRR is positive [Battese *et al.* (1993); Battese (1996) and Battese (1997)]. Applications can also be found in Ahmad and Qureshi (1999), and in Ahmad, Chaudhry, and Chaudhry (2000).

$UNIRR_{it}$ represents the crop area in acres not irrigated by any source;

$IRRA_{it}$ is irrigated crop area in acres;

$FERT_{it}$ is total fertiliser use in nutrient tonnes;

$RAINA_{it}$ represents the rainfall in inches in *i*th district and *t*th year multiplied by the total cropped area in *i*th district and in *t*th year;

$SLOAN_{it}$ is short-term loan advanced by the ADBP in *i*th district and *t*th year;

$LLOAN_{it}$ is long-term loan provided by the ADBP branches in *i*th district in $t-1$ year (lagged values);

T is time index assuming values from 1 for 1991-92 to 8 for the year 1998-99, representing technological change; and

D represents the dummy variable assuming the value of 1 for the *i*th district and zero otherwise.

The empirical estimation of the model given in Equation 10 is implemented using the two-step procedure explained in the previous section of the paper. However, squared term in the second step (Equation 7) is not used because of high correlation with the linear term, making almost all the estimates non-significant.[9]

4. RESULTS AND DISCUSSION

The parameter estimates of the model given in Equation 10, using alternative techniques, are presented in Table 1. All parameter estimates are significant at least at the 10 percent significance level, except those related to *Non-irrigated Dummy* in all three—the OLS, RE, and FE models, and *Short-term Loans* in case of the OLS model—which are not significant even at the 10 percent significance level. To select a model that suits the data best, various specification tests are performed and the results are presented in Table 2. Based on these specification tests, we have reached the following conclusions.

(a) The OLS excluding the districts effects is rejected in favour of FE formulation. This implies that without considering district-specific effects, the parameter estimates of the OLS model are biased because of the omitted variable problem [Griliches (1957); Mundlak (1961)].

(b) The RE model is rejected in favour of the FE model, which shows that the district-specific effects are correlated with variables included in the model. In case this association is not accounted for, the resulting estimates are affected by the simultaneous equation bias associated with the single equation production function [Hoch (1962)], in addition to the omitted variable problem mentioned in (a). This bias arises in a single equation estimation when the "random effects in the input level decisions are correlated with error terms in the production function" [Turvey and Lowenberg-DeBoer (1988), p. 296].

[9]The parameter estimates of the second step equation with the linear and squared time trends are not reported to save space, since the total estimates with squared term are more than 100 and without this the total comes out to be 68.

Table 1

Parameter Estimates: Cobb-Douglas Production Function, Using OLS, Fixed Effects and Random Effects Techniques

Variables	OLS		Random Effects Model		Fixed Effects Model		Fixed Effects without Credit Variables	
	Parameter Estimates	T-Ratio	Parameter Estimates	T-Ratio	Parameter Estimates	T-Ratio	Parameter Estimates	T-Ratio
Dummy Non-irrigated	–0.0128	–0.2520	0.0052	0.1180	0.0236	0.4580	0.0196	0.3750
Ln(Non-irrigated)	0.1358***	13.1460	0.0834***	7.0080	0.0675***	4.5310	0.0760***	5.0800
Ln(Irrigated)	0.3673***	14.7460	0.3736***	10.1330	0.3834***	6.7870	0.4052***	7.1100
Ln(Fertiliser)	0.2931***	11.6310	0.2466***	7.1090	0.2128***	4.6930	0.2230***	4.5870
Ln(Rainfall)	0.1255***	11.5880	0.0790***	6.9150	0.0664***	5.0060	0.7500***	5.6690
Ln(Short-term Loan)	0.0088	0.8010	0.0210***	2.9800	0.0236***	3.2770		
Ln(Long-term Loans)	0.0512***	2.7700	0.0113	0.8200	0.0073	0.5030		
Time	0.0208***	4.1000	0.0201***	7.1360	0.0197***	6.9330	2.3100***	8.5730
Constant	2.5361***	10.0720	3.6097***	14.2530				
Function Coefficient	0.98		0.81		0.76			
R^2	0.93				0.98		0.97	

*** Estimates are significant at least at the 10 percent significance level.

Table 2

Specification Tests for Alternative Models

Model	F Value	F Critical	χ^2 Value	χ^2 Critical	Result
No District Effects: OLS versus FE	19.18	1.40	–	–	Rejected OLS
Fixed versus Random			18.33	15.51	Rejected Random
No Credit Effect: $\beta_6 = \beta_7 = 0$	5.62	3.00	–	–	Rejected NCF

Given that the FE is a preferred specification, the contribution of both short-term and long-term loans has been jointly tested that led to the conclusion that agricultural loans play a significantly positive role in enhancing crop production. The comparison between the magnitudes of parameter estimates of fertiliser variable in the full FE as well as the restricted FE shows that the coefficients are very stable across models. This suggests the absence of any collinearity problem between the fertiliser variable and the loan variables.[10]

All of the above specification tests proved that the fixed effects model is the most preferred formulation for further analysis in this paper. Nonetheless, we can gain further confidence in this formulation by comparing the Function Coefficients (FC)—the sum of input elasticities, across models. The FC for the FE model (i.e., 0.76) is less than both the OLS (0.98) and the RE (0.81) models. This result is consistent with the argument demonstrated by Hoch (1958, 1962) that the simultaneous equation bias arising in a single equation production function estimation without incorporating the firm effects drives the FC closer to One—a tendency of exhibiting constant returns to scale. It is true whether the FC is less than One or greater than One. Moreover, the value of adjusted R^2 reflects that about 98 percent of the variation in output is caused by the independent variables included in the model, showing a good fit to the data.

The results regarding the decomposition analysis are provided in Table 3. The growth rates are computed at all the three levels—at the Punjab level, at the cropping system level, and at the district level. During the study period, total output grew at the rate of 2.6 percent per annum dominated by the contribution of higher factor productivity growth rate, i.e., 1.97 percent. The TFP growth result of this study ties in pretty well with the figures reported by Ali and Byerlee for the later period of their study, i.e., 1984–94, showing TFP growth of 1.60 percent per annum. The negative trends in technical efficiency indicate some doubts about the sustainability of the agricultural system as a whole; however, the negative impact

[10]Looking at the ADBP loan disbursement statistics, it shows that the production loans constitute 22 percent to 60 percent of the total disbursed loans in various districts and the rest are development loans, and more than 50 percent of the production loans are provided for the purchase of fertiliser. However, studies related to fertiliser use show that the contribution of institutional credit ranges from 0.6 percent to 3 percent for the purchase of fertiliser [Twyford *et al.* (1993); NFDC (1996) and NFDC (2000)].

appears to be negligible looking at the overall Punjab level. Considerable differentials in TFP growth are observed among various cropping systems of Punjab, showing reasonably high positive rates. The highest TFP growth is observed in *mungbean-wheat* followed by *barani*, *cotton-wheat, mixed* cropping zones and *rice-wheat* systems. The TFP measures are highly variable among the districts not only across Punjab but also within each cropping system (Table 3) and similarly in output growth.

The results also reveal that TFP growth is positively associated with education (correlation coefficient (corr) = 0.18) and district-level average farm size (corr = 0.36), but negatively associated with district-level average cropping intensity (corr = –0.68).[11] The results further indicate that TFP growth and the level of technical efficiency are negatively associated (corr = –0.23). This implies that relatively less efficient districts are catching up fast with the districts which are relatively more efficient and thus achieving greater achievable potential by using the given technology.

The *barani* area covering four districts of Punjab, i.e., Attock, Rawalpindi, Jehlum, and Chakwal, has very fertile lands, and the most popular crops are wheat, jawar, bajra, oilseeds, and maize. The average farm size in this region varies from 4.2 acres in Rawalpindi—the smallest size in Punjab having the highest cropping intensity in the region—to 9.6 acres in Attock (Appendix Table A). The rural male literacy rate in this region varies from 63 percent in Attock to 80 percent Rawalpindi. Khan and Iqbal (1982) (KI hereafter) and Ghaus, Pasha, and Ghaus (1996) (GPG hereafter), based however on different indicators, rank Attock district as relatively less developed in the region (Appendix Table A).

The TFP growth rate in the *barani* zone was around 3.2 percent per annum during the 1990s, dominated by the growth rates in technological change. The total output in the *barani* zone grew by 3.3 percent per annum, with about 99 percent contribution from the increases in TFP. Within this zone, the highest TFP growth is observed in Rawalpindi (5.6 percent), followed by Chakwal (4.8 percent) and Jehlum (2.0 percent), and the lowest is observed in Attock (0.4 percent). Attock in this region is the only district where growth in technical efficiency is negative, cancelling almost the entire impact of technological change. It may be due to the fact that this district is the least developed as compared not only with districts in its own region but also with most other districts in Punjab (see Appendix Table A).

The *wheat-mixed* zone includes 6 districts with the average farm size ranging from 6.6 acres in Faisalabad to 10.9 acres in Sargodha, while cropping intensity varies from 136 percent in Jhang and Sargodha to 161 percent in Okara (Appendix Table A).

[11]The correlations of average district-level TFP measures with the district-level indicators regarding the level of education, cropping intensity, and farm size are computed to see any systematic association at the province level.

Table 3

District-level Growth Rates in TFP, Inputs, and Total Output

Districts/Zones	T-Eff Growth	Techno. Change	TFP Change	Output Growth-due Input	Total Output Growth	Technical Efficiency Measures
Punjab	**–0.003**	**1.97**	**1.97**	**0.59**	**2.56**	
***Barani* Area**	**1.25**	**1.97**	**3.22**	**0.04**	**3.26**	
Attock	–1.57	1.97	0.4	1.6	2.00	0.84
R. Pindi	3.6	1.97	5.57	–0.77	4.79	0.76
Jehlum	0.18	1.97	2.15	1.21	3.36	0.49
Chakwal	2.78	1.97	4.75	–1.88	2.87	0.84
Mixed Zone	**–0.9**	**1.97**	**1.07**	**0.56**	**1.63**	
Sargodha	–1.48	1.97	0.49	0.43	0.91	0.69
Faisalabad	–1.04	1.97	0.93	0.59	1.53	0.77
T.T.Singh	–1.21	1.97	0.76	0.6	1.37	0.64
Jhang	0.2	1.97	2.17	0.44	2.61	0.71
Okara	–0.53	1.97	1.44	0.96	2.4	0.79
Kasur	–1.36	1.97	0.61	0.38	0.98	0.76
Rice-Wheat Zone	**–0.93**	**1.97**	**1.04**	**2.26**	**3.3**	
Gujrat	0.75	1.97	2.72	5.44	8.16	0.59
Sialkot	–1.28	1.97	0.69	0.47	1.16	0.66
Gujranwala	–0.94	1.97	1.03	2.64	3.67	0.77
Narowal	–1.35	1.97	0.62	5.49	6.11	0.58
Sheikhupura	–1.66	1.97	0.31	0.75	1.06	0.81
Lahore	–1.23	1.97	0.74	–0.16	0.58	0.51
Cotton-Wheat Zone	**–0.07**	**1.97**	**1.9**	**0.21**	**2.11**	**2.11**
Sahiwal	–0.22	1.97	1.75	–0.43	1.33	0.67
Multan	–0.05	1.97	1.92	–0.9	1.02	0.58
Khanewal	0.38	1.97	2.35	–0.62	1.73	0.63
Vehari	–0.67	1.97	1.3	–0.87	0.43	0.65
Lodhran	–1.25	1.97	0.72	0.85	1.57	0.5
Pakpatan	3.71	1.97	5.68	6.03	11.71	0.52
Bahawalpur	–2.17	1.97	–0.2	0.01	–0.19	0.79
R.Yar Khan	–1.77	1.97	0.2	0.24	0.44	0.94
Muzaffargarh	0.64	1.97	2.61	–0.59	2.03	0.65
D.G. Khan	0.76	1.97	2.73	–0.56	2.17	0.52
Rajanpur	1.67	1.97	3.64	1	4.65	0.56
Bahawalnagar	–1.03	1.97	0.94	0.47	1.41	0.72
Mungbean-Wheat	**1.60**	**1.97**	**3.57**	**–0.10**	**3.47**	
Khoshab	2.13	1.97	4.1	0.13	4.23	0.72
Mianwali	1.17	1.97	3.14	0.66	3.81	0.64
Bhakkar	3.49	1.97	5.46	–0.28	5.18	0.7
Layyah	–0.38	1.97	1.59	–0.92	0.66	0.51

The major crops of the region are wheat, sugarcane, pulses, rice, and cotton, sharing 44, 12, 10, 9, and 9 percent of the cropped area, respectively (Appendix Table B). The male literacy rate in the rural areas of *mixed-wheat* system varies from 43 percent in Okara to 59 percent in Sargodha and Toba Tek Singh districts. KI and GPG rank districts of Kasur, Jhang, and Okara as relatively less developed.

The TFP in *mixed-wheat* zone grew by about 1.1 percent per annum during the 1990s, with negative trends in growth of technical efficiency, (–0.90 percent), while the total output in the zone increased by 1.6 percent per annum, with dominant share of TFP. The highest TFP is observed in Jhang district (2.2 percent), followed by Okara (1.4 percent), Faisalabad (0.9 percent), Toba Tek Singh (0.8), and Kasur (0.6 percent), while Sargodha has shown a growth rate of 0.5 percent, the lowest in the zone. The reasons for the highest growth in Jhang district could be its relatively more diverse cropping pattern: during the study period, the share of acreage under cotton declined significantly, while the acreage under sugarcane, rice, and pulses increased during the 1990s. These changes in the cropping pattern might have helped the farmers move closer to the frontier. This is the only district in the mixed zone where the technical efficiency growth rate is positive though small. More area under pulses could be one of the reasons of this trend, since these crops improve soil fertility and also increase productivity of other crops sown on the same fields. The trends in technical efficiency in all other districts are negative, showing a serious concern about the sustainability of the system. A general rising trend in the area under sugarcane and rice has been observed during the 1990s in this zone, while the size of the area under cotton has declined. Moreover, rising water table, waterlogging and salinity, and the use of brackish underground water could be the major factors causing the decline in technical efficiency and thus pushing down the TFPs in the mixed-wheat crop zone.

The *rice-wheat* zone includes six districts. The average farm size ranges from 5.7 acres in Sialkot, the lowest size in the irrigated area of Punjab, followed by Gujrat, to 10.3 acres in Gujranwala (Appendix Table A). The cropping intensity varies from 129 percent in Gujrat to 177 percent in Lahore—the latter is the highest in Punjab. As regards the literacy rate among males in the rural areas of this zone, it varies from 50 percent in Lahore to 70 percent in Gujrat. The results show that the *rice-wheat* zone ranks the lowest among the cropping systems in terms of TFP growth, with 1.0 percent annual growth rate during the 1990s. However, the output growth, i.e., 3.3 percent per annum, was the second-highest among all the cropping systems with a major share of the inputs contribution—the latter is also the highest in the *rice-wheat* system among all the zones. That might have become possible due to the creation of three new districts[12] in this zone in the early 1990s, and because,

[12]Hafizabad from Gujranwala, Mandi Bahauddin from Gujrat, and Narowal from Sialkot. The data for the first two districts were added to their respective districts because of non-availability of data for first few years.

resultantly, the farming communities have had better access to input markets, agricultural extension services, credit facilities, etc. The physical infrastructure might have been developed quickly in these districts. The promotion of such facilities in rural areas not only increases farming efficiency but also promotes higher use and better mix of inputs, shifting the whole input output surface upwards. Nonetheless, these facilities do not appear to be improving the efficiency over time; this tendency could be due to the dominant factor of soil degradation in the rice belt.

The district-specific growth rates show that Gujrat remained the leader with 2.7 percent annual growth rate of TFP, followed by Gujranwala (1.0 percent), Sheikhupura (0.7 percent), Sialkot (0.7 percent), Narowal (0.6 percent), and Sheikhupura (0.3 percent). The cropping pattern in Gujrat, which includes Mandi Bahauddin, a newly-created district, has a very diverse cropping pattern; importantly, rice is the third major crop sown in the district after wheat and other minor grain crops—like jawar and bajra. Gujrat has the highest rural literacy rate and the lowest cropping intensity. All other districts show negative growth rates in efficiency. Rice is not only a major crop in the *kharif* season; its area of cultivation is also steadily increasing in the *rice-wheat* cropping zone. In total, more than 90–95 percent cropped area is shared by the wheat, rice, and fodder crops, thus depleting the minor and major nutrients of soil. This implies that soil degradation has become a serious problem in this zone which undermines the impact of technological change and thus reduces resource productivity.

The *cotton-wheat* zone includes 12 districts with average farm size ranging from 7.7 acres in Bahawalpur to 14 acres in Rajanpur (Appendix Table A). The cropping intensity in this zone has wide variability from 113 percent in Rajanpur to 165 percent in Vehari. Most of the districts are ranked very low on the development hierarchy—the rural male education ranges from 24 percent in Rajanpur to 51 percent in Sahiwal [Appendix Table A].

The *cotton-wheat* zone is placed third in terms of TFP performance among various cropping systems of Punjab, with average growth rate of 1.9 percent, while the output grew at the rate of 2.1 percent per annum during the 1990s. Out of the 12 districts, 7 have shown negative efficiency growth rates. The growth rates in TFP ranged from 5.7 percent in Pakpatan to negative growth rate, i.e., –0.2, in Bahawalpur. The same districts have shown respectively the highest positive growth rate and the highest negative growth rates in efficiency during the 1990s. The performance of Pakpatan district deserves special notice. This district was created in early 1990s and its hierarchical position on the development scale has not been determined and found in the literature. On the basis of education and health facilities, it is ranked among the relatively less developed districts by GPG. However, it is more likely that being a new district its infrastructure might have been developed fairly quickly. Nonetheless, its farmers appear to be good decision-makers who quickly changed their cropping pattern as cotton crop faced a countrywide crisis. The share of cotton in total cropped area dropped by almost 50 percent by the end of the 1990s; while the area under sugarcane, rice, maize, and vegetables increased during the same period. Bahawalpur district, which faced negative TFP, experienced a significant increase in area under cotton crop despite a severe attack of leaf curl virus during the first half of the 1990s. This district, on the other hand is characterised as having the second-lowest literacy rate, among males in the rural areas, after Rajanpur in the *cotton-wheat* system; also, it has the second-highest cropping intensity after Vehari in the cotton zone of Punjab.

In general, the performance of the *cotton-wheat* zone remained relatively poor during the 1990s. Its major cause appears to be the omnipresence of cotton leaf curl virus during the first half of the 1990s; in spite of the diminishing incidence of CLCV after the mid-1990s the production of cotton per acre never moved to the frontier once achieved at the beginning of this decade. Hussain (1999), using cross-sectional data for the 1996-97 crop season, concluded that the CLCV was the most significant variable in explaining the production inefficiencies of the cotton farmers in the *cotton-wheat* zone of Punjab. Looking at the district level socio-economic development ranking determined by KI, GPG, and the literacy rate reported by the 1998 Census of Population (Appendix Table A), one can draw an important conclusion, that the infrastructure and the factors affecting the management capacity of the farming community in the *cotton-wheat* zone are running too low to wrestle with the dynamism of the technologies in order to exploit their full potential. The conclusion of Ahmad and Battese (1997), that fields of the more educated and the experienced farmers were less infected by the CLCV disease during the 1993-94 crop season, also supports the above conclusion.

The *mungbean-wheat* zone includes four districts of Punjab—Khushab, Mianwali, Bhakar, and Layyah. The average farm size in this zone is fairly large as compared to the sizes in other cropping systems of the province and varies from 12.6 acres in Layyah to 18.4 acres in Bhakar. The latter is the largest average size among all districts of Punjab. The cropping intensity is relatively low in this region, varying from 103 percent in Bhakar to 137 percent in Layyah, portraying a usual inverse relationship between farm sizes and cropping intensity. The male literacy rate in the rural areas of this zone ranges from 46 percent in Bhakar district to 61 percent in Mianwali (Appendix Table A).

The *mungbean-wheat* cropping system, however, has shown the highest growth rate of TFP—3.5 percent per annum dominated by the effect of technological change. The output in this district grew at the rate of 3.5 percent exclusively due to growth in TFP—thanks to the high-yielding varieties of mungbean. The perusal of the cropping pattern in this zone indicates that the share of guarseed has significantly dropped and the area has substituted by mungbean crop during the second half of the 1990s. The reasons for this crop substitution could be several, including greater year-to-year price variability and relatively cumbersome harvesting and threshing activities of guarseed crop, and may be due to high profitability of the mungbean. Moreover, mungbean is a legume crop and has the ability to improve soil fertility; consequently, it also increases the productivity of other crops in rotation [Ali *et al.* (1997)]. However, the performance of Layyah remained relatively poor during the 1990s. It faced a declining trend in efficiency, and the inputs contribution declined also. While scanning the data regarding this district it appears that the farming community is going through a transitional period of moving from a mixed and a very diversified cropping pattern to a some sort of specialised cropping system like that of other districts in the system. Declining trend in area under wheat and guarseed is observed; while the area under pulses, gram, and cotton has increased significantly. Area under sugarcane and *mungbean* remained highly variable during the 1990s. This change in the cropping pattern could be the potential source of loss of productive efficiency. The last column of Table 3 indicates that Layyah district is among the least efficient districts in Punjab. It has the highest cropping intensity in the *mungbean* cropping system (Appendix Table A). Moreover, the problem of waterlogging and salinity is also a serious problem in the district.

As regards the distribution of district-level efficiencies, Table 4 reveals that the *cotton-wheat* system remained relatively inefficient during the 1990s, with 75 percent of the districts having an efficiency level of less than 70 percent. The second relatively inefficient cropping system was the *rice-wheat*—with 67 percent of the districts falling below the efficiency level of 70 percent. *Barani* system appears to be relatively more efficient as compared to other systems, with one out of four districts falling below the efficiency level of 70 percent. These results imply that there is tremendous scope to increase the output by using the given resources and technology more efficiently. The range of this expected increase varies from 6 percent in Rahim Yar Khan district to 51 percent in Attock district.

Table 4

Distribution of District-level Efficiencies

Range of Technical Efficiency Measures	*Barani*	Mixed-Wheat	Rice-Wheat	Cotton-Wheat	Mungbean-Wheat	Total Districts
Less than 0.60	1 (25%)	0	3 (50%)	5 (42%)	1 (25%)	10 (31%)
0.60 to Less than 0.70	0	2 (33%)	1 (17%)	4 (33%)	1 (25%)	8 (25%)
0.70 to Less than 0.80	1 (25%)	4 (77%)	1 (17%)	2 (17%)	2 (50%)	10 (31%)
Equal and Greater than 0.80	2 (50%)	0	1 (17%)	1 (8%)	0	4 (13%)
Total Districts	4 (100)	6 (100)	6 (100)	12 (100)	4 (100)	32 (100)

5. CONCLUSION AND POLICY IMPLICATIONS

The major objective of this paper is to analyse the agricultural productivity growth differentials at three levels in Punjab—district, cropping system, and the province. This paper estimates the production frontier using the ordinary least squares, random effects, and fixed effects approaches. The fixed effects time variant technical efficiency model is considered to be the most preferred formulation.

The results of growth analysis show that the crop output increased at the rate of 2.6 percent per annum, dominated by the share of TFP growth. Wide variation exists among cropping systems as well as within the system both in TFP growth and output growth. The *mungbean-wheat* zone emerged as a leader in TFP growth with 3.6 percent per annum, followed by *barani* (3.2 percent), *cotton-wheat* (1.9 percent), *mixed-wheat* (1.1 percent), and *rice-wheat* (1.0 percent). The TFP growth rates in different cropping systems are dominated by the technological change component. The results show negative growth rates in technical efficiency in three of the cropping systems that are *rice-wheat*, *mixed-wheat,* and *cotton-wheat*. The negative trend in rice zone could be due to the dominant factor of land degradation; prevalence of leaf curl virus disease in the cotton zone during the 1990s appears to be the major cause for negative trend in cotton; the increasing problem of waterlogging and salinity and the use of brackish underground water may be among the potential sources of the negative trends in efficiency in the mixed zone of Punjab. The other reasons could be the low literacy rate among the farmers in most of the districts of the latter two cropping systems. Moreover, the majority of these districts are also characterised as having a very low status in the development ranking determined by Khan and Iqbal (1982) in rural areas, and worked out by Ghaus, Pasha, and Ghaus (1996) based on education, health, and water supply at the district level in Pakistan.

The data, during the 1990s, show that the area under rice and sugarcane crops, which are highly water-intensive crops, had increased in most of the districts of *mixed-wheat* and *cotton-wheat* zones. The reason of this trend could be the high instability in cotton output growth as compared to rice and sugarcane.[13] Other reasons include high volatility in year-to-year prices; greater vulnerability of this crop to diseases and insect attack; consistently rising production cost due to soaring prices particularly of insecticides and pesticides, along with a serious concern of their quality; incapacity of the farming communities to deal with the dynamism of technology in cotton production; and increasing waterlogging and salinity problem, etc. This rising trend in rice and sugarcane cultivation in the *cotton-wheat* system would aggravate the land

[13]Growth instability (Gi) can be calculated as: Gi=var(Ga)+var(Gy)+2covar(Ga,Gy), where Ga and Gy represent growth rates in area and yield per acre. The instability measures using Punjab data indicate that Gi's for rice, sugarcane, and cotton were respectively about 36, 151, and 630 during the 1970s; 71, 119, and 1289 during the 1980s; and 133, 369, and 135 during the 1990s. This suggests that the rice output remained the least instable as compared to sugarcane and cotton during the last three decades.

degradation problem—ultimately driving the cotton crop out of the system as it happened in the now *rice-wheat* and *mixed-wheat* zones [Mohammad (1963)]. Consequently, the expansion of the rice and sugarcane area in the cotton-growing system is not justifiable and is not in the interest of the country in the long run.

To save the cotton economy from this substitution, instability in cotton output price needs to be reduced with active participation of the Trading Corporation of Pakistan, and the farmers have to be protected from exploitation by the chemical dealers and seed companies which are selling sub-standard products and uncertified seed. Moreover, research studies and the census data, as discussed in the previous section, indicate that most of the districts in the *cotton-wheat* system carry low socio-economic development ranking, implying poor management potential to confront the dynamic changes in technology and in a highly unionised cotton marketing and processing economy. Therefore, there is need to develop the necessary infrastructure and expand general as well as agricultural education and health facilities.

The results also indicate that 5 out of six districts of the *rice-wheat* system have shown negative growth rates in technical efficiency, with abating growth rates of TFP. These districts have the highest cropping intensity in Punjab. About 80 percent of the cropped area is occupied by wheat and rice. Adding the share of fodder would raise this figure to more than 90 percent, depleting the soil nutrients—the major as well as the micronutrients. Using green manure and growing leguminous crops can improve fertility and the physical condition of the soil [Ahmad, Ahmad, and Gill (1998)]. Besides, the use of major nutrients like Nitrogen, Phosphorus, and Potash needs to be improved in quantity and for a balanced mixture. Moreover, the use of Gypsum needs to be popularised, particularly in areas where underground water is brackish.

The results further indicate that TFP growth is positively associated with farm size, and shows negative association with the level of technical efficiency. These results imply that the following measures need to be taken in order to improve productivity, on the one hand, and to sustaining it, on the other—using the given level of technology: (1) there is need to encourage investment in corporatising the input and processing sectors, and in other agro-based employment-intensive rural industries—this would encourage marginal and inefficient farming communities to opt for more rewarding work and let other farmers increase their farm size to a viable production unit[14]; and (2) there is enormous scope to expand output, and also productivity, by increasing the productive efficiency of the relatively inefficient districts, and by sustaining that of those which are already there. This can only be done by encouraging investment in rural physical infrastructure, providing efficient and effective institutional support, including agricultural extension, soil survey and testing, inputs quality control service, etc.

[14]However, there is a need for a detailed study to determine an optimal farm size in various provinces of the country, since no such study is found in the literature using Pakistan data.

Appendices

Appendix Table A

Ranks of Districts of Punjab, Farm Size, Cropping Intensity, Bullock Cultivation, and Illiteracy among Farmers

Districts	A-KI[a]	B-KI[a]	C-KI[a]	GPG[b]	FZ Acres[c]	CI%[c]	Educ %
Attock	17	20	20	11	9.6	105	63
Rawalpindi	21	7	7	1	4.2	117	80
Jehlum	20	13	13	4	7.7	101	74
Chakwal	–	–	–	2	9.1	100	73
Sargodha	13	9	9	12	10.9	136	59
Faisalabad	6	4	4	6	6.6	142	54
T.T. Singh	–	–	–	9	8.0	147	59
Jhang	5	11	11	26	10.6	136	47
Okara	–	–	–	16	9.3	161	43
Kasur	4	15	15	24	8.5	161	45
Gujrat	11	3	3	5	6.0	129	70
Sialkot	9	1	1	7	5.7	159	62
Gujranwala	2	5	5	8	10.3	173	58
Narowal	–	–	–	10	–	–	64
Sheikhupura	3	8	8	17	8.4	163	49
Lahore	1	18	18	3	8.7	177	50
Sahiwal	7	2	2	13	8.4	156	51
Multan	10	6	6	15	9.9	162	42
Khanewal	–	–	–	14	9.4	162	50
Vehari	8	16	16	21	9.6	165	46
Lodhran	–	–	–	29	–	–	40
Pakpatan	–	–	–	28	–	–	44
Bahawalpur	12	17	17	27	7.7	163	36
R.Y. Khan	15	10	10	22	7.9	157	38
Muzaffargarh	16	12	12	30	9.6	148	37
D.G. Khan	19	21	21	20	10.3	121	37
Rajanpur	–	–	–	32	14.0	113	24
Bahwalnagar	18	14	14	18	12.4	135	42
Khushab	–	–	–	23	15.3	105	58
Mianwali	14	19	19	19	13.3	114	61
Bhakar	–	–	–	31	18.4	103	46
Layyah	–	–	–	25	12.6	137	50

Source: [a]Khan and Iqbal (1982); [b]Ghaus, Pasha and Ghaus (1996); [c]Pakistan (1994).

Note: (1) A-KI—Here the rankings show the availability of inputs and facilities that affect the level of production, and the indicators include irrigation facility, cottage industry, sweet drinking-water, electricity, tractors, tubewells; B-KI—indicates the distance at which the facilities or services are located from the village, showing economic well-being and quality of life, and the ranking is based on metalled road, grain market, fertiliser depot, office of the field assistant, diesel pumps, tractor workshop, veterinary hospital, bank, schools, etc.; C-KI—Composite of indicators in A-KI and B-KI. (2) GPG—is based on various indicators of health and education both in the urban and rural areas. (3) The original ranking that was for all districts in Pakistan has been re-ranked for Punjab only—thus, the ranking numbers may differ from the sources. (4) "–" indicates non-availability of ranking, since these districts were created in later years.

Appendix Table B

Cropping Pattern in Different Zones

Crops	*Barani*	Mixed-Wheat	Rice-Wheat	Cotton-Wheat	Mungbean-Wheat
Wheat	0.55	0.44	0.46	0.46	0.37
Cotton	–	0.09	–	0.37	0.02
Sugarcane	–	0.12	0.03	0.02	0.03
Rice	–	0.09	0.34	0.04	–
Maize	0.07	0.05	0.02	0.02	–
Bajra, Jawar, and Barley	0.20	0.03	0.05	0.03	0.05
Pulses	0.05	0.10	0.03	0.01	0.40
Oilseed	0.11	0.02	0.02	0.03	0.02
Vegetables and Fruits	0.01	0.07	0.05	0.04	0.01

REFERENCES

Ahmad, B., and M. A. Chaudhry (1997) An Overview of Pakistan and Indian Punjab Agriculture in Retrospect. *Journal of Rural Development and Administration* 29, 56–80.

Ahmad, Bashir, Munir Ahmad, and Z. A. Gill (1998) Restoration of Soil Health for Achieving Sustainable Growth in Agriculture. *The Pakistan Development Review* 37:4, 997–1015.

Ahmad, Munir, and A. Ahmad (1998) An Analysis of the Sources of Wheat Output Growth in the Barani Area of the Punjab. *The Pakistan Development Review* 37:3, 231–249.

Ahmad, Munir, and G. E. Battese (1997) A Probit Analysis of the Incidence of the Cotton Leaf Curl Virus in Punjab, Pakistan. *The Pakistan Development Review* 36:2, 155–169.

Ahmad, Munir, M. G. Chaudhry, and G. M. Chaudhry (2000) Some Non-price Explanatory Variables in Fertiliser Demand: The Case of Irrigated Pakistan. *The Pakistan Development Review* 39:4, 477–486.

Ahmad, Munir, and S. K. Qureshi (1999) Recent Evidence on Farm Size and Productivity Relationship: Implications for Public Policy. *The Pakistan Development Review* 38:4, 1135–1153.

Ali, Shujat (2000) Productivity Growth in Pakistan's Agriculture 1960–1996. A Ph.D. Thesis, Department of Economics, Simon Fraser University, Burnaby, B. C., Canada.

Ali, M., and D. Byerlee (2000) Productivity Growth and Resource Degradation in Pakistan's Punjab: A Decomposition Analysis. (A Draft.) World Bank, Washington, D.C.

Ali, M., I. A. Malik, H. M. Sabir, and B. Ahmad (1997) *The Mungbean Green Revolution in Pakistan.* Taiwan: Asian Vegetable Research and Development Centre.

Ali, M., and J. C. Flinn (1989) Profit Efficiency Among Basmati Rice Producers in Pakistan Punjab. *American Journal of Agricultural Economics* 71, 303–310.

Battese, G. E., S. J. Malik, and M. A. Gill (1996) An Investigation of Technical Inefficiencies of Production of Wheat Farmers in Four Districts of Pakistan. *Journal of Agricultural Economics* 47, 37–49.

Battese, G. E., S. J. Malik, and S. Broca (1993) Production Functions for Wheat-farmers in Selected Districts of Pakistan: An Application of a Stochastic Frontier Production Function with Time-varying Inefficiency Effects. *The Pakistan Development Review* 32:3, 233–268.

Battese, G. E. (1997) A Note on the Estimation of Cobb-Douglas Production Functions When Some Explanatory Variables Have Zero Values. *Journal of Agricultural Economics* 48, 250–252.

Battese, G. E. (1996) On the Estimation of Production Functions Involving Explanatory Variables Which Have Zero Values. Department of Econometrics, University of New England, Armidale, Australia. (Working Paper in Econometrics and Applied Statistics No. 86.)

Byerlee, D., and A. Siddiq (1994) Has the Green Revolution been Sustained? The Quantitative Impact of the Seed-Fertiliser Revolution in Pakistan Revisited. *World Development* 22, 1345–1361.

Carter, M. R. (1989) The Impact of Credit on Peasant Productivity and Differentiation in Nicaragua. *Journal of Development Economics* 31, 13–36.

Chaudhry, M. G., Manzoor A. Gill, and G. Mustafa Chaudhry (1985) Size Productivity Relationship in Pakistan's Agriculture in the Seventies. *The Pakistan Development Review* 24:3&4, 349–361.

Cornwell, C., P. Schmidt, and C. Sickles (1990) Production Frontier with Cross-Sectional and Time-Series Variation in Efficiency Levels. *Journal of Econometrics* 46, 185–200.

Fecher, F., and P. Pestieau (1993) Efficiency and Competition in O.E.C.D. Financial Services. In H. O. Fried, C. A. K. Lovell and P. Schmidt (eds) *The Measurement of Productive Efficiency Techniques and Application*. New York: Oxford University Press.

Ghaus, A. F. A., H. A. Pasha, and R. Ghaus (1996) Social Development Ranking of Districts of Pakistan. *The Pakistan Development Review* 35:4, 593–614.

Griliches, Z. (1957) Specification Bias in Estimation of Production Functions. *Journal of Farm Economics* 39, 8–20.

Hobbs, P., and M. L. Morris (1996) Meeting South Asia's Future Food Requirements from Rice-Wheat Cropping Systems: Priority Issues Facing Researchers in the Post-Green Revolution Era. Mexico, D.F.: International Maize and Wheat Improvement Centre. (Natural Resource Group Paper 96-01.)

Hoch, I. (1962) Estimation of Production Function Parameters Combining Time-Series and Cross-Sectional Data. *Econometrica* 30, 34–45.

Hoch, I. (1958) Simultaneous Equation Bias in the Context of the Cobb-Douglas Production Function. *Econometrica* 26, 566–758.

Hussain, Sajid (1999) An Analysis of the Efficiency of Cotton Farmers in the Punjab in Pakistan. Unpublished Ph.D. Thesis, University of New England, Armidale, NSW, Australia.

Kalirajan, K. P. (1991) The Importance of Efficient Use in the Adoption of Technology: A Micro Panel Data Analysis. *Journal of Productivity Analysis* 2, 113–126.

Khan, M. H., and Mahmood Iqbal (1982) Socio-economic Indicators in Rural Pakistan: Some Evidence. *The Pakistan Development Review* 2:3, 217–230.

Kmenta, J. (1986) *Elements of Econometrics.* New York: Macmillan Publishing Company.

Lall, S. (1993) Understanding Technology Development. *Development and Change* 24, 719–53.

Mohammad, Ghulam (1963) Some Physical and Economic Determinants of Cotton Production in West Pakistan 3, 491–526.

Mundlak, Y. (1961) Empirical Production Function Free of Management Bias. *Journal of Farm Economics* 43, 44–56.

NFDC (2000) *Fertiliser Use at Farm Level in Pakistan*. Islamabad: National Fertiliser Development Centre.

NFDC (1996) *Fertiliser Use on Wheat: Farm Level Survey Rabi 1991-92.* Islamabad: National Fertiliser Development Centre.

Nishimizu, M., and J. M. Page (1982) Total Factor Productivity Growth, Technological Progress and Efficiency Change: Dimensions of Productivity Change in Yugoslavia, 1975-78. *Economic Journal* 92, 920–936.

Pakistan, Government of (Various Reports) 1998 Districts Census Reports of (Various Districts of Punjab). Population Census Organisation, Statistics Division, Islamabad.

Pakistan, Government of (1994) 1990 Census of Agriculture, Punjab, Province Report Vol. II, Part 2. Agricultural Census Organisation, Economic Affairs and Statistics Division, Lahore.

Pakistan, Government of (Various Issues) Agricultural Statistics of Pakistan. Food and Agriculture Division (Planning Unit). Islamabad: Ministry of Food, Agriculture and Cooperatives.

Parikh, A., and K. Shah (1994) Measurement of Technical Efficiency in the North West Frontier Province of Pakistan. *Journal of Agricultural Economics* 45, 132–138.

Punjab, Government of (Various Issues) *Development Statistics of Punjab.* Lahore: Punjab Bureau of Statistics.

Randhawa, M. S. (1954) Out of the Ashes. Public Relations Department, Punjab, Chandigar: p. 8.

Rosegrant, M. W., and R. E. Evenson (1993) Agricultural Productivity Growth in Pakistan and India: A Comparative Analysis. *The Pakistan Development Review* 32:4, 433–451.

Srinivasan, T. N. (2001) Developing Countries in the World Trading System: From GATT, 1947, to the Third Ministerial Meeting of WTO, 1999. Yale University Economic Growth Centre. (Reprint No. 566.)

Turvey, C. G., and J. Lowenberg-DeBoer (1988) Farm-to-Farm Productivity Differences and Whole Farm Production Functions. *Canadian Journal of Agricultural Economics* 36, 295–312.

Twyford, I. T., M. I. Bajwa, and M. T. Saleem (1993) *Fertiliser Use at Farm Level in Pakistan.* Islamabad: National Fertiliser Development Centre.