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Is There Any Role of Technological Inputs? A District-wise Analysis of Output Differential in Crop Sector

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I. INTRODUCTION

The idea of inclusive growth has emerged over time that highlighted systematically excluded segments of society from enjoying the benefits of growth on the basis of religion, ethnicity or location. In Pakistan, districts-wise allocation and usage of technological inputs is the outcome of growth and the important contributing elements as well to enhance specifically crop sector output under the advancement in growth prospective. It is reported that crop sector output contributes around 40 percent of the total agricultural GDP,[1] where 2/3rd belongs to Punjab.[2] The introduction of advance technological inputs provides an opportunity to enhance production potentials of crop sector in different provinces and their respective districts because Pakistan is also facing the problem of low agricultural productivity in comparison to many developed and developing countries of the world.[3] Secondly, the expansion of opportunities to enhance economic freedom in long run has been considered an important issue that needs to be addressed in inclusive growth process. Hence, understanding the interrelationship among different farm related inputs effecting crop sector would help to measure (i) the impact of increased total traditional and technological inputs; (ii) contributive aspects of both types of technological inputs; machine and bio-chemical; and (iii) districtwise differential especially considering their resource endowments and availability.

Agricultural Technology

Technological change in agricultural sector mostly referred as mechanisation.[4] As Ruttan (1960) has identified three dimensions of technological change; firstly, individual

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[1]Mahboob-ul-Haq Human Development Centre (2003) "*Human Development in South Asia 2002*" a special report on 'Agriculture and Rural Development' p.175–176.

[2]Punjab province contributes significant proportion of agricultural products of whole country, especially in crop sector, such as 80.4 percent in the production of wheat, 78.2 percent in the production of cotton, about 70 percent in the production of sugarcane and 59.3 percent in the production of cleaned rice (PDS–2005, p. 95).

[3]See Table 1, which elaborates that Pakistan has lowest average yield kg per hectare in production of all major crops including Maize among countries like France, Mexico, Egypt, China and India.

[4]Most of the studies have analysed the impact of mechanical tools such as tractors, threshers and combines harvesters over the farm productivity by ignoring other elements of technology such as biological and informative impacts.

changes in the techniques of production; secondly, changes in output per unit of each input accounted for with *partial productivity* measures, and thirdly, output per unit of total input determined through *total factor productivity* measure.[5] Two major ways were also referred to show the effect of technological change on traditional market. Initially, technological changes has led to multiply: (i) The amount and variety of information relevant for decision making; and (ii) The possibilities and advantages of direct control over quality at the production level, and lastly the production of many agricultural commodities has become feasible in substantial amount due to technological and organisational innovations.[6]

Economic impact of technological change can be observed through adoption of new techniques that further modify the cost structure or product mix and shift in demand and factors` supply curve.[7]

Domestic Perspective

Agriculture is the leading sectors of Pakistan's economy where Punjab province is the major contributor. The introduction of new technologies has provided an opportunity to build up high production capacity. As in Table 1, Pakistan national average in case of Wheat and Cotton per unit land output is close to world average yield per hectare but less than China and Egypt. In case of Rice and Sugarcane, production per unit of land is comparatively very low. In Punjab, wheat yield average is almost equal to world level but more than national average, Cotton yield average is double than world, and national levels but less than China. Rice yield average is much lower than India, China, and world averages, to some extent, same applies to Sugarcane where Egyptian average is double than the world average. During 1960s introduction of mechanical tools such as tubewells

Table 1

Comparison of National Average Yields of Pakistan with Other Countries

Country	Average Yield (Kg / Hectare)			
	Wheat	Cotton	Rice	Sugarcane
World	2,720	1,788	3,916	65,802
India	2,770	7,54	2,915	68,049
China	3,885	3,978	6,266	66,802
Egypt	6,006	2,654	–	119,838
Mexico	5,151	–	–	74,746
France	7,449	–	–	–
Pakistan National Avg.	2,262	1,867	2,882	48,056
Progressive Farmer	4,500	2,890	4,580	106,700
Punjab Avg.*	*2649*	*3054*	*1636*	*47698*

Source: Vision 2030, p. 79, Working Draft, Planning Commission, Government of Pakistan.
*On the basis of 2000-2005 data.

[5]Ruttan (1960) "*Research on the Economics of Technological Change in American Agriculture*". p. 736.

[6]*ibid*, p. 748.

[7]Nerlove and Bachman (1960) "The Analysis of Change in Agricultural Supply". *Journal of Farm Economics* 42, 531–54.

and pumps lead to increase the productivity of agriculture sector in manifold.[8] During 1970s the exponential growth of tractors and then later addition of threshers and combine harvesters opened new avenues to increase the productive capacity in agriculture sector.

It is, therefore, the objective of this study is to identify how technological inputs lead to enhance the production potential per unit land area in different districts especially focusing the interactive behaviour of traditional and technological inputs. It would further help to redesign effective policies and reduce regional differences by augmenting total crop production to achieve the goals of inclusive growth effectively.

This paper is organised in such a way that Section II elaborates literature review with theoretical frame work of the study. In third section, research design, data and methodology have been discussed along with the rationality of using factor analysis. Procedure of statistical analysis with ranking and indices construction methods has also been explained in the same section. Results and limitation are interpreted in fourth and fifth sections respectively. Moreover, Section VI refers policy recommendation. Finally the last section concludes the paper.

II. LITERATURE REVIEW

A large number of renowned researchers have tried to measure and evaluate the role of technological elements in the process of economic growth and prosperity especially its relation with productive potentials in different sectors of the economy [Solow (1957); Salter (1966); Kuznets (1966); Kennedy and Thrilwall (1972); Sen (1975), Carlaw, Kenneth, and Lipsey (2003)].[9] Many others focused on the agriculture sector considering the components of technological change as a driving force of economic affluence [Kendrick (1958); Meiburg (1962); Schultz (1964); Wilbanks (1972); Hayami and Ruttan (1985); Giannakas, Schoney, and Tzouvelekas (2001)].[10] Technological change is also considered the source of most growth in productive capacity in the long run, since continued investment in capital that embodies traditional technology very quickly faces low marginal returns [Schultz (1964); Hayami and Ruttan (1985)]. Some of the researchers have analysed the output differential on the basis of regions, sectors or even among inputs by considering the difference in resource endowments [Yamaguchi and Binswanger (1975); Adams and Bumb (1979); Edison Dayal (1984); Hayami and

[8]Ghaffar, M. and S. R. Bose (1970) "Output effects of Tubewells on the Agriculture of the Punjab: Some Empirical Results". *The Pakistan Development Review*, No.10, (Spring), p. 68–86.

[9]Kennedy, C., and A. P. Thrilwall (1972) "Surveys in Applied Economics: Technical Change", *Economic Journal*, Vol. 82, No. 325, pp. 12–72; Salter, W. (1966) *Productivity and Technical Change.* (2nd ed) London: Cambridge University Press; Solow, R. M. (1957) "Technical Change and Aggregate Production Function", *Review of Economic and Statistics,* Vol. 39, No. 3, pp. 312-320: Sen, A. (1975) *Employment, Technology and Development.* Oxford University Press.

[10]Kendrick, J. N. (1958) "Productivity Trends in Agriculture and Industry". *Journal of Farm Economics,* Vol. 40, pp. 1554–1564; Thomas J. Wilbanks (1972) "Accessibility and Technological Change in Northern India". *Annals of the Association of American Geographers,* Vol. 62, No. 3, pp. 427-436.

Ruttan (1985); Konstantinos, *et al*. (2001); Barrett, *et al*. (2004); Tu and Deng (2005)].[11]

Therefore, the analysis of farm and non-farm related technological change is an emerging field of interest because of rapid growth in innovations, techniques and factor combinations to explore its implications for agricultural growth and development in regional perspective.

Theoretical Framework

Conventionally agricultural output can be observed through the relationship of output per hectare to traditional inputs such as labour, animal power, water and to modern inputs include fertilisers, pesticides, agricultural machinery and equipments. However, multiple other factors like education to make labour more skilful and knowledgeable, credit availability for farming activities, sources of communication that impart better techniques with least cost, as well as improved infrastructure through provision of market to farm and farm to market roads have also contributed over the long run in enhancing the crop output. Since technological inputs can be applied at different stages of production process hence divided into two forms of inputs; first one is the Mechanical or Machine-Capital inputs that can further be classified into five categories as mentioned in Table 2.

Table 2

Categories of Equipments

Category	Type	Equipment in respective category
1.	Levelling and Cultivating Equipments	Blade/Plank, Cultivator, Mould Board Plough, Disk Plough, Chisel Plough, Ripper/ Sub-Soiler, Rota-Vator, Bar/Disk Harrow, Ridger, and Border Disk
2.	Sowing, Fertilising and Spraying Equipments	Drill, Row Crop Planter, Sugarcane Planter, Potato Planter, Fertiliser Broad-Caster, Fertiliser Ridger and Tractor Mounted Sprayer
3.	Harvesting Equipments	Reapers, Cutter Binders, Threshers and Combine Harvesters
4.	Haulage Equipments	Tractor-trolley, Delivery Van and Trucks
5.	Miscellaneous Equipments and Machines[12]	Seed-delinter, Seed-treater, Seed-grader/cleaner, Water Tank, etc.

[11]Tu Jianjun and Deng Yulin (2005) "Comprehensive Evaluation on Agricultural Environment in Western China". *Journal of Mountain Science,* Vol. 2, No.3. pp. 244–254; Adams, John, and Bumb, Balu. (1979) "Determinants of Agricultural Productivity in Rajasthan, India: The Impact of Inputs, Technology, and Context on Land Productivity", *Economic Development and Cultural Change,* Vol. 27, No. 4, pp. 705–722; Barrett, Christopher B., Moser, Christine M., Oloro V. McHugh, and Barison, Joeli (2004) "Better Technologies, Better Plots, or Better Farmers? Identifying Changes in Productivity and Risk Among Malagasy Rice Farmers", *American Journal of Agricultural Economics*, Vol. 86, No. 4, pp. 869; Konstantinos Giannakas, Schoney, Richard., and Tzouvelekas, Vangelis (2001) "Technical Efficiency, Technological Change and Output Growth of Wheat Farms in Saskatchewan", *Canadian Journal of Agricultural Economics*, No. 49, pp. 135–152; Edison Dayal. (1984) "Agricultural Productivity in India: A Spatial Analysis", *Annals of Association of American Geographers*, Vol. 74, No. 1, pp. 98–123; Yamaguchi, Mitoshi., and Binswanger, Hans P. (1975) "The Role of Sectoral Technological Change in Development: Japan, 1880-1965", *American Journal of Agricultural Economics*, Vol. 57, No. 2, pp. 269–278.

Whereas, second is Bio-capital inputs that includes fertilisers and pesticides mainly. First two categories of machine capital are required during the preparation of cultivation, sowing and gestation period of crop plantation while third category of equipments and machines are needed when crops are ripened and ready for mowing. Haulage equipments are used to transport the commodities from farm to market.

The basic purpose of this study i.e., to evaluate and investigate empirically the crop sector environment under the context of new technologies and their significant impact over the output potentials of agriculture sector in different districts of Pak-Punjab[13], can be hypothesised as "*technological inputs are significantly contributing to enhance the level of output in crop sector by augmenting traditional inputs and even replacing them to some extent.*"

III. RESEARCH DESIGN AND METHODOLOGY

In agriculture, diversified variables are involved with interdependence in multiple dimensions that need to be converged into few comprehensive but legitimate dimensions, which is possible through multivariate techniques such as 'component analysis' that helps to establish correlation among different independent input-variables.[14] This method identifies those sets of variables which may explain major part of the variation out of total variance in output mostly referred as 'principal component factors', resultantly all the variables can be apportioned among these principal components on the basis of their respective associations with each other. Secondly, as a by product, factor scores are derived during the construction of principal components which can further be used to develop comprehensive scores applied here to assign the ranks to the respective unit of analysis i.e., districts.

Data

Data is collected from various publication issued by Government of the Punjab and its respective departments.[15] This study has focused complete set of thirty five years period (1971-2005), which has been segmented into seven phases each covered averages of five years data. However, two phases (first and last one) have been selected for ranking purpose then indices are constructed for all seven phases considering the first phase as base period.

[12]This category has not been considered effectively in analysis: firstly it has emerged in the final phase only with trivial figures not allowing to use it for comparative analysis; secondly, it contained the equipments related to seed which was not included in this study.

[13]Four major crops are focused only including wheat, rice, cotton and sugarcane. Crop output capacity is measured for each individual crop independently as well as jointly by using their respective yield and area sown for that purpose in each district.

[14]Principal Component (Factor) Analysis has been applied to measure agricultural performance and to develop socio-economic-status indices in different researches [Banks (1954); Adams and Bumb (1979); Brook, *et al*. (1986); PERI (1998, 2001); Sahn and Stifel (2003); and Vyas and Kumaranayake (2006)] Complete References are available on demand.

[15]Sources include various issues of Pakistan Census of Agriculture: Punjab, Punjab Development Statistics; Pakistan Census of Agricultural Machinery; Crop Yielding Department; Agricultural Information Centre, Directorate of Agriculture, and Meteorological Centre, Lahore.

Evaluation Factor System: Rational

There are three main reasons that ensure the originality of data in factor analysis procedure.

(i) It incorporates regional differentiations: since different districts of Punjab contains complicated land forms with uneven climatic situations that leads to establish basic differences in crop production environment.
(ii) It integrates systematic interdependencies: agriculture contains different sub-systems where some factors dominate the others along with socio-economic-environmental influences.
(iii) It congregates the multidimensional relations of agricultural inputs into few specific dimensions without loss of originality of data to ascertain the simplified understanding of a complicated system.[16]

On the basis of above stated reasons four subsystems are selected to establish factor evaluation system. These are:

- ***Land Usage***: primarily includes land use intensity, land use pattern, cropping intensity, irrigation, rainfall and cropping pattern.
- ***Technological Capital***: levelling and cultivating equipments, sowing, fertilising and spraying equipments, tractors, fertiliser, plant protection, harvesting equipments and haulage equipments and vehicles.
- ***Labour Powers:*** consists of farm labour force, and animal power.
- ***Infrastructural Resources:*** such as roads, credit, literacy, communication, and urbanisation.

Statistical Analysis

To calculate comprehensive scores for each selected district, factor analysis technique is applied in the given stepwise procedure:[17]

– First step leads to determine the standardised factor matrix with *i*variables and *j*-districts (i = 1, 2, ……20 and j = 1, 2, ….34).
– Second step is to calculate the characteristic vector, unit characteristic vector and variance contribution percentage. Selected number of principal component (n) is determined by accumulated contribution percentage, which should be more than 85 percent.
– Third step is to determine factor loading matrix and then rotate it to explain principal factors.
– Fourth step involves the calculation of score for each principal component F_{ij} (where i = 1,2….n, and j = 1,2,…34).
– Fifth step is to calculate comprehensive score for each case, and then convert them into percentage and arrange in order.

$$Z_i = \sum F_{ij} (W_j)$$

[16]Tu and Deng (2005), p. 245.
[17]Tu and Deng (2005), p. 249; factor analysis has been performed through SPSS.

Where i = 1,2,…n, j = 1,2, …34, W_j is the variance contribution percentage of principal component in districts j.

After computation, the results are derived which explain the accumulated variance contribution percentage of four principal components F_1 to F_4 mounted to 85.027 percent. Therefore, their percentage variance contribution is determined as weight for calculating comprehensive score for each case. In order to arrange the sequence, each score has been converted into percentage. On the basis of this comprehensive score all districts are ranked in both selected phases.

After assigning the ranks to each district in two selected phases, all seven phases are used to construct simple weighted indices on the basis of the same variables as already employed for ranking purpose.[18] These indices help to cluster the variables to comprehend the patterns of changing share in total crop output. First phase (1971-75) is considered as base period (=100) to develop the indices. Comparison among selected districts on the basis of these indices has been performed from second phase (1976-80) onwards.

Construction of Indices

Different indices are constructed for each selected district. Each index contained group of variables on the basis of their attributes. The procedure is given in four main steps:

Step – I: index values are measured for each individual variable by assuming first phase (1971-75) as a base period.

Step – II: weights are calculated for each individual variable included in the respective index on the basis of given technique:

$$IV_i^k = \sum_{i=2}^{i=7} R_i W_i$$

Where,

IV_i^k = k-th Index Value in i-th phase

W_i = weight of each variable in i-th phase in its respective index as calculated by taking the sum of ratios for the k-th index of each variable to sum of the index values of all variables added in that index.

R_i = respective value of each variable in given index in i-th phase

k = individual input index name

Step – III: respective weights are multiplied with index value of each variable added in the respective index. Then all included variables' values are summed up in each index to get single value of all respective indices.

$$\left(R_i^2 \Big/ \sum_{i=2}^{7} R_i \right)_k$$

[18]Weights have been assigned on the basis of proportional contribution of given variable in each phase

Step – IV: for each respective *i*-th phase, proportional contribution (PC_i) of each input index into total crop out is calculated by using Crop Output Index (COI_i) to observe the various patterns over the time with the help of the formula mentioned below:

$$PC_i^k = \left({k_i} \Big/ {\sum_{i=2}^{7} k_i} \right) \times COI_i$$

Table 3

Indices and Their Respective Variables

Index Name	Variables
Crop Output Index (COI)	Wheat-Land-Output
	Rice-Land-Output
	Cotton-Land-Output
	Sugarcane-Land-Output
Power Resource Index (PRI)	Farm Labour Force
	Animal Power
Technological Capital Index (TCI)	Tractors
	Land Cultivating Equipment
	Sowing Fertilising Spraying Equipment
	Harvesting Equipment
	Haulage Vehicle
Land Crop Composition Index (LCCI)	Farm Intensity
	Cropping Intensity
	Cropping Pattern
Water Resource Index (WRI)	Rainfall
	Tubewells
	Irrigation
Bio-Chemical Index (BCI)	Plant Protection
	Fertilisers
Infrastructural Development Index (IDI)	Roads
	Urbanisation
	Literacy
	Communication

Since multiple variables are used to develop different indices and each respective index reflects a particular dimension as well as includes different number of variables therefore to make values of each index comparable its respective value is divided by respective number of variables.

IV. RESULTS AND ANALYSIS

Initially, nineteen districts are ranked in the first phase of analysis, but in the final seventh phase, thirty four cities have actually attained the status of district (see Tables 4 and 5 in Appendix A). Hence only nineteen previously established districts are focused for analysis to compatibility in comparison. The primary purpose of assigning different ranks to the respective districts is to explore the potentials and contribution in overall crop production in the Punjab province, which might be the outcome of advance technology in terms of application of mechanical and bio-chemical inputs. Results obtained through ranking procedure provided the foundation to compare and analyse the different districts by selecting four each from top and low ranks, and one more selected as a special case to analyse their typical performance with respect to their differences in input-combination and allocation by considering resultant impact over the crop production. Four selected high ranked districts are Lahore, Gujranwala, Sahiwal and Faisalabad, whereas four at bottom include Dera Ghazi (DG) Khan, Mianwali, Muzaffargarh and Gujrat. Districts Rahim Yar (RY) Khan has been considered as special case because it performed very well and improved its rank from 11th out of 19 to 2nd out of 34 districts in respective phases.

Output Indices[19]

In these selected nine districts of the Punjab, seven districts have demonstrated a continuous upward growth in crop production as measured through Crop Output Index (COI). The upward growth pattern is more consistent in case of Lahore, Gujranwala and Sahiwal, however, in case of Faisalabad it remains inconsistent and during the last phase even declining trend has been observed perhaps causing very small adverse impact on the ranking status of this district. Low ranked districts like Dera Ghazi Khan and Mianwali could not maintain higher crop output levels consistently over the study period.

Input Indices

It is observed in case of all the selected districts that Power Resource Index (PRI) has slowly but consistently declined over the years, revealing the fact that chiefly most of the technological inputs applied in agricultural farming activities have increased the supply of physical power and speed to complete a piece of job in cultivation, harvesting and haulage process. Further, bio-chemical inputs that are used to compensate the deficiencies and helped to revive the vitality and fertility in farm land areas ensure enhanced potentials of crop output per unit land.

Further analysis also revealed that in most of the districts the use of traditional inputs have either declined or remained stagnant over time at a very small scale of contribution. In case of Lahore, Faisalabad and Gujranwala districts, some of the traditional inputs have grown with small proportional shares. However, in Lahore as a top ranked district, Technological Capital Index (TCI) shared in small proportions but Bio-Chemical Index along with Water Resource Index (WRI) and Land Crop Composition Index (LCCI) has significantly contributed in total provincial crop production. It strengthened the fact that growth in traditional inputs is also required to augmenting the crop output in some districts.

District-wise Analysis

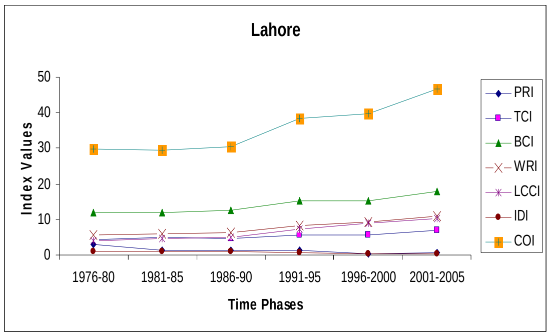
Each selected district is now individually analysed with reference to the behaviour of input as reflected through traditional inputs indices WRI, LCCI, IDI, PRI, and more advanced and technological input indices TCI, and BCI.

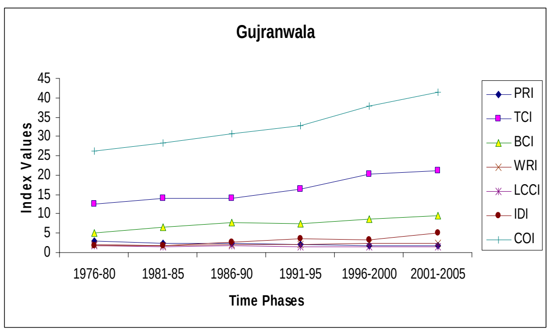
[19]See Indices Tables in Appendix B.

High Ranked Districts

District Lahore

The proportional contribution of BCI is significantly higher than other input indices, which is a sign of deteriorating land quality. Rising proportions of Water Resource Index is strengthening this argument as well. Land composition remained as an important factor in comparison to mechanical technology instruments. However, both technological input indices together consist of about 55 percent of total inputs contribution in overall crop production as reflected by Crop Output Index (COI) which has increased up to 56 percent from already higher level of 30 percentage points to 47 percentage points.



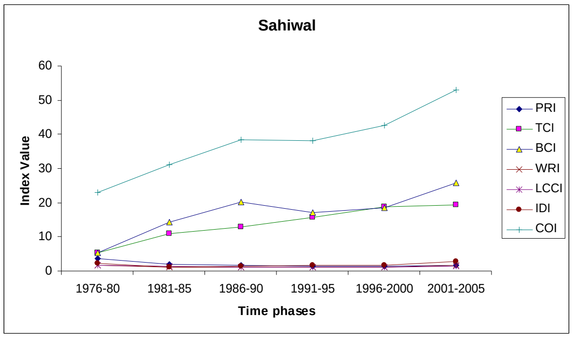


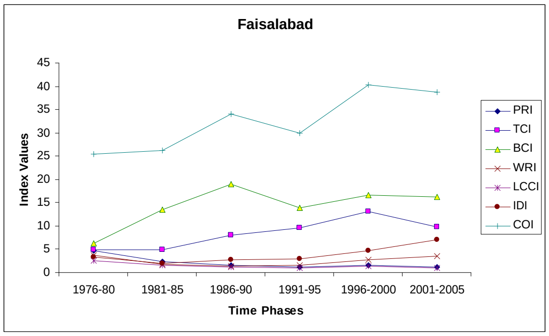
District Gujranwala

In case of Gujranwala, the growth in Crop Output Index is about 58 percent points because technological inputs contributed in a more significant manner. TCI and BCI together increased from 68 percent to 74 percent and make it obvious that traditional inputs are responsible for one fourth of the total change in crop output only. Here, BCI contributed lesser than TCI, reason may be the better natural conditions in this district which have successfully prevented the quality of land from deteriorating. To some extent growth patterns of crop output just followed the pattern of TCI. Another important element is the infrastructural improvements that are quite visible in the last phase of the study may elaborate that it is possible to boost up the crop output by increasing infrastructural facilities even if technological and traditional inputs failed to continue their pace of growth.

District Sahiwal

Technological inputs indices started to grow rapidly but traditional input indices declined over the study period. Crop Output Index has followed the pattern of Bio-Chemical Index that has shown significant contribution. A consistent but decelerating rise has been observed in Technological Capital Index as well. Crop Output Index has grown from 23 percentage points to 53 percentage points that reflects a pronounced growth of 132 percent over the study period. The technological inputs have eventually contributed up to 86 percent from 52 percent in the beginning.





District Faisalabad

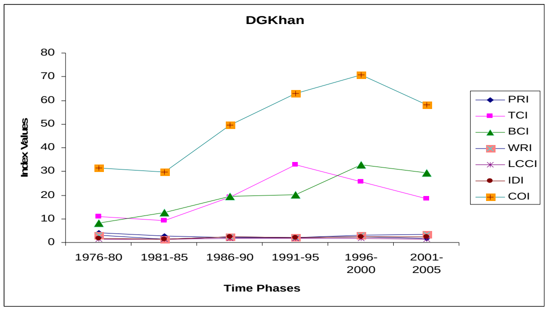
Cyclical behaviour in growth patterns of crop output has been observed in Faisalabad district. In the initial two phases, second and third, bio-chemical index has shown rapid rising pace that reverted back in the fourth phase but again slowly came back towards higher levels in the last two phases. A continuous rise has been observed in technological capital index from third phase up to the sixth phase afterward it declined. However, traditional input indices picked higher growth rates but failed to resist the downward trends in crop output especially during fifth and seventh phases which endorsed their ineffectiveness. Crop output index has grown up to 53 percent points perhaps ensure the higher rank for this district. Another, important observation is the growing trends of traditional inputs categorically in the last phase along with downward trends of technological inputs and crop output. This demonstrates that only the technological inputs are augmenting the production process otherwise increasing traditional inputs are not so vibrant in this regard at least in Faisalabad district.

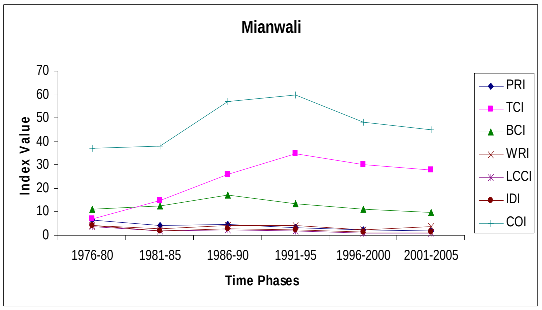
Now it can be concluded that even the growth reflected by crop output index in most of the districts is close to 55 percent points on average except Sahiwal, but the important aspect is the steady growth of technological inputs specifically bio-chemical inputs, which can be considered as important factor to increase crop output.

Low Ranked Districts

District Dera Ghazi Khan

In D.G. Khan, from 3rd to 6th phases crop production exhibited rising growth patterns but in seventh phase, this trend reverted downwards. Again, like other districts traditional input indices either remain stagnant or grown very slowly while technological input indices have grown as a whole with inconsistent behaviour. Here crop output index has followed the trend determined by technological capital index up to fifth phase then onwards COI pattern has switched to BCI. Reason may be that the decline in TCI has been compensated by rise in BCI during sixth phase. However, in final phase both BCI and TCI are responsible for significant decline in crop output index because traditional inputs indices remain stagnant.



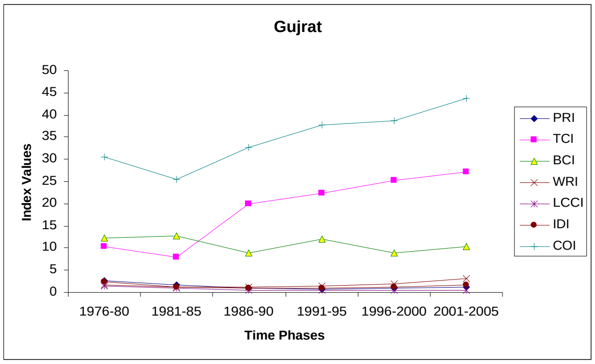


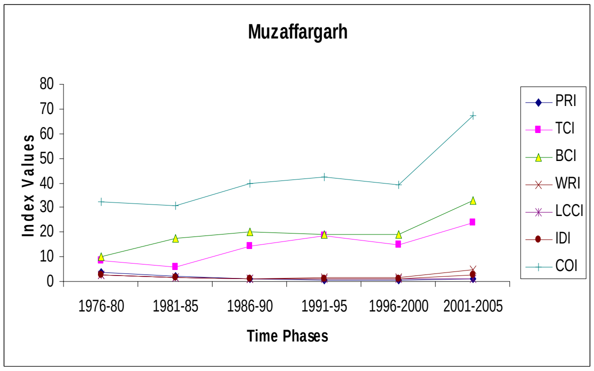
District Mianwali

In case of Mianwali district, TCI continued to grow up to end of fifth phase then it declined, whereas BCI slowly increased initially but move down later. Growing trends in crop output index continued to increase upward with decreasing rate until the end of fifth phase then fell down. Hence, as a whole in this district, it is obvious that only combination both types of technological inputs can set the pattern of change in the crop output.

District Gujrat

Crop output index has followed approximately the growth patterns of biochemical input index. However, low level of BCI with inconsistent pattern has caused some disturbances in the growing behaviour of crop out index. Nevertheless, it strengthened the argument that at least one of the technological input must increase to augment the crop production because consistent rise in TCI from third phase onwards has maintained COI at higher levels.





District Muzaffargarh

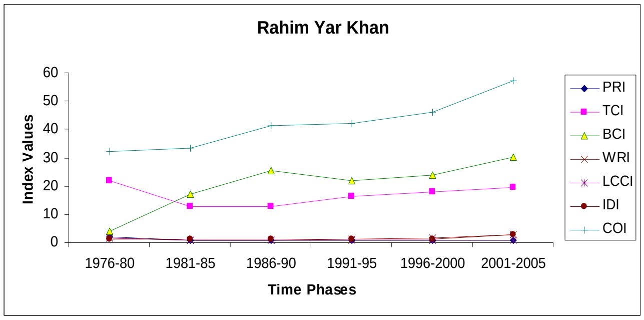
In this district, 108 percent point drastic increase in crop output has been observed with inconsistent and skewed manner. Actually from second phase to sixth phase 20 percent points improvement has occurred only, but a drastic rise up to 73 percent points has been observed during the final seventh phase. In most phases, crop output index generally followed the technological capital index trends without getting influence from opposite trends in biochemical inputs` index. During the last seventh phase both types of technological inputs has grown perhaps to complement each other along with a little improvement in traditional input indices implanting the boost in crop output.

It can be concluded that the greater proportional contribution of technological inputs are necessary to enhance the production capacity but not just sufficient. The persistent growth in both type of technological inputs or at least in one of them, which suits the particular district most, is indispensable to ensure continuous growth in crop out put.

Special Cases

District Rahim Yar Khan: The Achiever

This district showed a significant and consistent growth in crop output index that is 78 percentage points. Both TCI and BCI contributed jointly to enhance the levels of output in this district. TCI has declined during initial two phases but compensated due to exorbitant growth in Biochemical input index during the same era. From sixth phase onwards, COI followed the pattern set by BCI but continue to grow slowly due to positive growth in TCI that remained successful to nullify some of the negative impacts of BCI on COI.



V. LIMITATIONS OF ANALYSIS

Some limitations are observed during data collection such as: (i) Rainfall data was available only for selected stations on one time basis which has been replicated over the selected time phases in other districts as well on the basis of propinquity, (ii) Communication is measured through licensing that reduces over the time in number due to the reasons beyond the scope of this paper which may contradict the actual scenario. (iii) 'Credit' as a part of "Infrastructural Development Index" kept outside the Index even though it is used for ranking procedure because when "Credit" employed in infrastructural index it has overlapped all other indices due to huge proportional rise in monetary amount that might be because of decreased value of money over time. Secondly, the total number of technological machine input available in each district is assumed as the proxy to reflect the application of these inputs in the same district in each respective phase. Thirdly, all districts cannot be focused for analysis by assuming that selected districts are able to explore and identify those aspects that lead to create output differences among the districts.

VI. RECOMMENDATION AND POLICY IMPLICATIONS

Now it is suggested that mainly total availability of technological inputs per unit area of land should be increased in about all the districts especially in low ranked on priority basis where declining trends have been observed specifically during recent phases. Further, it should be ensured that the expansion in use of these technological inputs must be consistent and growing over the time with the objective to obtain optimal factor-input combinations in the long run to ensure the consistency in the crop output over the years. Shift of dependence from traditional inputs towards technological inputs, after achieving a critical level of their application, need to be augmented through better allocation of both traditional and technological resources in crop sector in the Punjab province.

These results are important for policy measure to follow the goals of inclusive growth in terms of reduction in regional growth potentials and provision of opportunities to contribute in overall growth process such as: (a) balance growth can be achieved to the extent of the potentials available in different districts along with the prospective reduction in regional disparities; and (b) greater proportions of agricultural resources be used to provide technological inputs to poor farmers.

VII. CONCLUSION

It is concluded that ranking procedure has strengthened by this fact that higher ranks are achieved by those districts where (i) crop production levels remained higher than others; (ii) traditional inputs are supported by technological inputs; and (iii) applied technological inputs have consistently grown in number. Secondly, in most of the cases, crop output has grown with the same pace and direction as determined by those technological inputs. This fact provides the evidence that technological inputs have now become the essential part of the crop production activities. The evidence of successive growth of these inputs also get support from previously conducted study as in Bangladesh where it has been observed that contribution of mechanical power has raised to 52 percent in 2000 from 11 percent in 1980.[20] On the basis of above analysis it can be concluded that traditional inputs, no doubt, are important and necessary for crop output but over the time their role and contribution is diminishing up to some critical extent whereas the role and share of technological inputs is expanding over the time. As supported by the United States Department of Agriculture Economic Research Service (USDA) in economic brief where it is reported that crop (corn) yield has increased through greater use of agricultural inputs such as more fertilisers and machinery per unit of land.[21]

If high ranked districts are compared with low ranked districts then it is evident that firstly, consistency in provision and growth of both types of technological inputs is essential to reduce the districtwise differences in crop output, secondly, traditional inputs—especially infrastructural and water related—need to be increased as well in some cases. Thirdly the objectives of inclusive growth can only be achieved if low ranked districts are provided the opportunities to apply technological inputs with the equal proportions as are used in high ranked districts but with more consistent and rising pace over the long run.

[20]Alam, M. S., Alam, M. R., and Islam, K. K. (2005) "Energy Flow in Agriculture: Bangladesh", *American Journal of Environmental Sciences*, Vol. 1, Issue 3, pp. 213–220.

[21]Fuglie, Keith O., Heisey, Pual W. (2007) "*Economic Returns to Public Agricultural Research*", Economic Brief Number 10, September, United States Department of Agriculture (USAD), Economic Research Services.

Appendices

APPENDIX A

Ranking Tables

Table A1

Comprehensive Score based Ranking for Districts of Punjab, Pakistan: Data 1971-75

% of Variance (after Rotation)	28.651	23.665	21.774	18.912		
Districts	Score of F1	Score of F2	Score of F3	Score of F4	Comprehensive Score	Ranks
Lahore	0.98912	2.59678	0.42674	–0.16971	95.87435706	1
Gujranwala	–0.48284	–0.17797	2.97692	0.4023	54.38224479	2
Sahiwal	1.69583	–0.25668	–0.75187	1.11587	47.24500919	3
Faisalabad	1.27893	0.4688	0.02457	–0.14729	45.48621413	4
Multan	1.29528	–0.11333	–0.10117	0.25996	37.14260077	5
Sialkot	–0.75431	–0.33451	1.13393	1.47659	23.08754694	6
Sheikhupura	–0.16474	–0.2975	1.72239	–0.16262	22.66754718	7
Rawalpindi	–1.11816	2.82425	–0.55486	–0.23367	18.29878541	8
Rahim Yar Khan	1.42416	–0.5713	–0.37563	–0.55348	8.63741228	9
Bahawalpur	0.4595	–0.53735	–0.17102	0.03973	–2.52366897	10
Gujrat	–0.43858	–0.39422	–0.14543	1.17567	–2.82729366	11
Jhang	0.40316	–0.44426	–0.15555	–0.11964	–4.61205312	12
Bahawalnagar	0.51522	–0.6598	–0.62328	–0.06735	–15.6976207	13
Sargodha	–0.13539	–0.21046	–0.5851	0.12935	–19.15329499	14
Attock	–1.35583	–0.43585	–1.3191	1.45274	–50.4081401	15
Jhelum	–1.34047	0.2792	–0.8549	–0.08317	–51.98604161	16
Muzaffargarh	–0.33559	–0.45692	–0.05794	–1.62509	–52.42328853	17
Mianwali	–1.32428	–0.57686	–0.63005	–0.11223	–67.43454064	18
D. G. Khan	–0.61103	–0.702	0.04135	–2.77795	–85.75568603	19

Table A2

Comprehensive Score based Ranking for Districts of Punjab, Pakistan: Data 2001–05

% of Variance (after Rotation)	29.798	13.771	12.879	11.868	10.935	5.775		
Districts	Score of F1	Score of F2	Score of F3	Score of F4	Score of F5	Score of F5	Comprehensive Score	Ranks
Lahore	0.65975	4.75239	–0.22971	–0.16887	–0.69011	–0.47943	69.82675	1
Rahim Yar Khan	0.91055	–0.51153	–0.2662	1.73856	0.21624	0.94274	45.10204	2
Gujranwala	0.43193	1.23964	0.38595	–0.3869	1.70506	–0.78063	44.45735	3
Vehari	1.03376	–0.61981	1.07118	1.40973	–0.82729	–0.35915	41.67447	4
Faisalabad	0.62937	0.46085	0.63443	–0.84507	–0.4591	3.35787	37.61331	5
Sahiwal	0.71646	–0.49847	1.19277	0.54132	–0.62195	0.63467	33.13491	6
Lodhran	0.92467	–0.56164	0.53707	1.27568	–0.89112	–0.08747	31.62613	7
Toba Take Singh	0.17667	0.15728	0.44887	0.91175	0.14022	0.74344	29.85863	8
Multan	1.09112	0.45115	–0.1426	0.27725	–0.95321	–0.27998	28.1396	9
Okara	0.79891	–0.45958	0.96584	–0.23391	0.00349	0.08743	27.68312	10
Sialkot	–0.44994	0.19373	0.97847	0.0733	2.75608	–1.44325	24.53515	11
Khanewal	0.71088	–0.53164	0.44066	0.89735	–0.4308	–0.40745	23.12278	12
Bahawalpur	0.76079	0.20997	–1.39309	1.64395	–0.03719	–0.90643	21.489	13
Sargodha	0.20866	0.26328	0.30649	–0.81154	0.34815	1.75038	18.07467	14
Bahawalnagar	0.56198	–0.16389	–0.69697	1.08476	–0.14109	–0.50916	13.90339	15
Sheikhupura	0.50141	0.0427	0.18694	–0.95785	0.80577	–0.27734	13.77833	16
Mandi Baha-ud-Din	–0.16576	0.00507	–0.36906	–0.55712	2.06964	0.99037	12.11638	17
Pakpatten	0.61626	–0.9013	1.96522	–0.38726	–1.0688	–0.95833	9.443896	18
Muzaffargarh	0.45266	–0.27536	–1.59956	0.91618	1.0234	–0.31594	9.335197	19
Kasur	0.50747	0.0502	0.29972	–0.4689	–0.27086	–0.46613	8.454329	20
Hafizabad	0.42583	–0.02172	0.62801	–1.1418	0.34043	–1.41182	2.496376	21
Jhang	0.5623	–0.32005	–0.6099	–1.25457	0.20088	1.63726	1.255667	22
Narowal	–1.02653	–0.41105	0.68317	–0.00461	1.93644	–0.60024	–9.79669	23
Gujrat	–1.09099	–0.31483	1.53196	–0.14494	0.31643	0.9019	–10.1662	24
Layyah	0.0105	–0.78003	–0.73881	–0.54982	0.80895	–0.03397	–17.8196	25
D.G. Khan	0.2271	–0.30216	–2.08698	–0.25565	–0.19063	0.04489	–29.1315	26
Rajanpur	–0.06561	–0.41813	–2.71408	0.08181	–0.26115	0.07851	–44.0991	27
Rawalpindi	–2.02483	1.56112	0.76255	0.11206	–1.37206	–0.43625	–45.2097	28
Jhelum	–2.62725	0.42889	–0.49909	1.21519	0.19593	1.47607	–53.7197	29
Mianwali	–0.53379	–0.2426	–0.80995	–1.04063	–0.91013	–0.71607	–56.1158	30
Bhakkar	–0.03406	–0.97126	–0.43914	–2.20012	–0.71578	–0.89983	–59.1804	31
Attock	–2.03983	–0.3598	0.23123	0.68892	–0.71154	–0.52311	–65.3852	32
Khushab	–0.4946	–0.54184	–0.61297	–2.17917	–1.49964	–0.48989	–75.1843	33
Chakwal	–2.36587	–0.6096	–0.04243	0.72094	–0.81467	–0.26363	–81.3142	34

APPENDIX B

OUTPUT AND INPUT INDICES TABLES

High Ranked Districts

Lahore

Index Name	Time Phases					
	1976-80	1981-85	1986-90	1991-95	1996-2000	2001-2005
PRI	2.93	1.46	1.41	1.23	0.31	0.60
TCI	4.42	4.82	4.61	5.70	5.79	6.86
BCI	12.05	11.92	12.44	15.09	15.14	17.77
WRI	5.52	5.97	6.28	8.42	9.38	10.82
LCCI	3.94	4.54	4.86	7.27	8.96	10.14
IDI	1.11	0.89	0.91	0.64	0.22	0.49
COI	29.96	29.59	30.51	38.35	39.80	46.67

Gujranwala

Index Name	Time Phases					
	1976-80	1981-85	1986-90	1991-95	1996-2000	2001-2005
PRI	2.93	2.37	2.29	1.96	1.92	1.88
TCI	12.51	14.15	13.98	16.44	20.24	21.11
BCI	5.11	6.54	7.74	7.47	8.54	9.49
WRI	2.06	1.87	2.10	1.97	2.34	2.51
LCCI	1.69	1.55	1.77	1.57	1.41	1.43
IDI	1.93	1.75	2.76	3.43	3.35	4.95
COI	26.22	28.23	30.63	32.85	37.80	41.36

Sahiwal

Index Name	Time Phases					
	1976-80	1981-85	1986-90	1991-95	1996-2000	2001-2005
PRI	3.59	1.98	1.75	1.48	1.40	1.63
TCI	5.37	10.89	12.87	15.66	18.73	19.46
BCI	5.25	14.42	20.27	17.09	18.53	25.79
WRI	1.73	1.23	1.07	1.10	1.11	1.76
LCCI	1.78	1.36	1.24	1.08	1.21	1.47
IDI	2.32	1.24	1.30	1.61	1.75	2.88
COI	22.87	31.12	38.50	38.02	42.72	53.00

Faisalabad

Index Name	Time Phases					
	1976-80	1981-85	1986-90	1991-95	1996-2000	2001-2005
PRI	4.61	2.33	1.53	1.24	1.57	1.16
TCI	4.84	4.98	8.12	9.56	13.20	9.74
BCI	6.32	13.54	18.95	13.81	16.69	16.27
WRI	3.80	1.78	1.43	1.51	2.66	3.53
LCCI	2.63	1.56	1.21	1.00	1.34	1.02
IDI	3.24	2.03	2.79	2.84	4.78	7.10
COI	25.43	26.22	34.02	29.97	40.23	38.82

Low Ranked Districts

Dera Ghazi Khan

Index Name	Time Phases					
	1976-80	1981-85	1986-90	1991-95	1996-2000	2001-2005
PRI	4.24	2.59	2.21	1.92	2.49	1.82
TCI	10.96	9.13	19.08	32.75	25.70	18.39
BCI	8.08	12.79	19.62	20.33	32.67	29.33
WRI	3.23	1.21	2.50	1.98	3.08	3.39
LCCI	1.53	1.41	1.75	1.55	1.75	1.32
IDI	1.74	1.31	2.27	2.17	2.28	2.28
COI	31.34	29.59	49.55	62.81	70.66	58.13

Mianwali

Index Name	Time Phases 1976-80	1981-85	1986-90	1991-95	1996-2000	2001-2005
PRI	6.67	4.27	4.48	3.18	2.10	1.66
TCI	7.09	14.75	26.13	34.78	30.14	27.79
BCI	11.14	12.41	17.06	13.64	11.23	9.76
WRI	4.36	2.72	4.24	4.13	2.29	3.56
LCCI	3.89	1.89	2.44	1.73	1.11	0.79
IDI	4.16	1.86	2.84	2.36	1.47	1.62
COI	37.31	37.90	57.18	59.83	48.35	45.18

Gujrat

Index Name	Time Phases 1976-80	1981-85	1986-90	1991-95	1996-2000	2001-2005
PRI	2.53	1.57	0.96	0.79	1.08	1.26
TCI	10.33	7.82	20.04	22.38	25.32	27.06
BCI	12.16	12.69	8.84	11.96	8.81	10.31
WRI	1.63	1.26	1.27	1.37	1.82	3.03
LCCI	1.42	0.91	0.57	0.40	0.49	0.51
IDI	2.35	1.27	1.03	0.85	1.14	1.66
COI	30.42	25.51	32.71	37.76	38.66	43.83

Muzaffargarh

Index Name	Time Phases 1976-80	1981-85	1986-90	1991-95	1996-2000	2001-2005
PRI	3.91	1.86	0.93	0.77	0.77	1.10
TCI	8.64	5.79	14.06	18.62	15.00	23.69
BCI	9.87	17.62	20.36	19.08	19.23	32.99
WRI	2.75	1.58	1.26	1.47	1.60	4.65
LCCI	2.43	1.57	1.15	0.99	0.94	1.21
IDI	2.52	1.40	1.11	0.96	0.91	2.44
COI	32.39	30.99	39.80	42.64	39.05	67.53

Special Case

Rahim Yar Khan

Index Name	Time Phases 1976-80	1981-85	1986-90	1991-95	1996-2000	2001-2005
PRI	1.94	0.97	0.61	0.65	0.86	0.91
TCI	21.77	12.59	12.57	16.42	17.77	19.54
BCI	3.87	16.96	25.24	21.93	23.67	30.21
WRI	1.59	0.99	0.98	1.11	1.58	2.97
LCCI	1.50	0.98	0.79	0.72	0.77	0.82
IDI	1.37	1.08	1.24	1.24	1.38	2.63
COI	32.05	33.57	41.42	42.07	46.03	57.09

REFERENCES

Adams, John, and Balu Bumb (1979) Determinants of Agricultural Productivity in Rajasthan, India: The Impact of Inputs, Technology, and Context on Land Productivity. *Economic Development and Cultural Change* 27:4, 705–722.

Ahmad and Amjad (1984) *The Management of Pakistan's Economy 1947-82.* Karachi: Oxford University Press.

Alam, M. S., M. R. Alam, and K. K. Islam (2005) Energy Flow in Agriculture: Bangladesh. *American Journal of Environmental Science* 1: 3, 213–220.

Barrett, Christopher B., M. Christine Moser, Oloro V. McHugh, and Joeli Barison (2004) Better Technologies, Better Plots, or Better Farmers? Identifying Changes in Productivity and Risk among Malagasy Rice Farmers. *American Journal of Agricultural Economics* 86: 4.

Carlaw, Kenneth I., and Richard G. Lipsey (2003) Productivity, Technology and Economic Growth: What is the Relationship. *Journal of Economic Surveys* 17:3, 457–495.

Dobi, T., K. McFarland, and N. Long (1986) Raw Score and Factor Score Multiple Regression: An Evaluative Comparison*.* *Educational and Psychological Measurement* 46:2, 337–347.

Edison, Dayal (1984) Agricultural Productivity in India: A Spatial Analysis. *Annals of Association of American Geographers* 74:1, 98–123.

Fuglie, Keith O. and Pual W. Heisey (2007) Economic Returns to Public Agricultural Research. September, United States Department of Agriculture (USAD), Economic Research Services. (Economic Brief Number 10.)

Ghaffar, M. and S. R. Bose (1970) Output Effects of Tubewells on the Agriculture of the Punjab: Some Empirical Results*. The Pakistan Development Review* 10:1, 68–86.

Hayami, Y. and V. Ruttan (1985) *Agricultural Development: An International Perspective*. Revised and Expended Edition. Baltimore, MD: John Hopkins University Press.

Kawagoe, Toshihiko, Yujiro Hayami, and Vernon W. Ruttan (1985) The Intercountry Agricultural Production Function and Productivity Differences among Countries. *Journal of Development Economics* 19: 1-2, 113–132.

Kendrick, J. N. (1958) Productivity Trends in Agriculture and Industry. *Journal of Farm Economics* 40, 1554–1564.

Kennedy, C. and A. P. Thrilwall (1972) Surveys in Applied Economics: Technical Change. *Economic Journal* 82: 325, 12–72.

Konstantinos, Giannakas, Richard Schoney, and Vangelis Tzouvelekas (2001) Technical Efficiency, Technological Change and Output Growth of Wheat Farms in Saskatchewan*. Canadian Journal of Agricultural Economics* 49, 135–152.

Kuznets, S. (1966) *Modern Economic Growth*. New Heaven, CT: Yale University Press.

Lastovicka and Thamodaran (1991) Common Factor Score Estimate in Multiple Regression Problems*. Journal of Marketing Research* 28: 1 (February), 105–112.

Meiburg, Charles O. (1962) Nonfarm Inputs as a Source of Agricultural Productivity. *Journal of Farm Economics* 44:5, 1433–1438.

Salter, W. (1966) *Productivity and Technical Change*. (2nd ed). London: Cambridge University Press.

Schultz, T. W. (1964) *Transforming Traditional Agriculture*. New Heaven, CT: Yale University Press.

Sen, A. (1975) *Employment, Technology and Development.* Oxford University Press.

Skrondal, A. and P. Laake (2001) Regression Among Factor Scores. *Psychometrika* 66: 4 (December), 563–575.

Solow, R. M. (1957) Technical Change and Aggregate Production Function. *Review of Economic and Statistics* 39:3, 312–320.

Tu, Jianjun and Deng Yulin (2005) Comprehensive Evaluation on Agricultural Environment in Western China. *Journal of Mountain Science* 2:3, 244–254.

Wilbanks, Thomas J. (1972) Accessibility and Technological Change in Northern India. *Annals of the Association of American Geographers* 2:3, 427–436.

Yamaguchi, Mitoshi, and Hans P. Binswanger (1975) The Role of Sectoral Technological Change in Development: Japan, 1880-1965. *American Journal of Agricultural Economics* 57:2, 269–278.

Zaidi, S. Akbar (2006) *Issues in Pakistan Economy* (eds.). Karachi: Oxford University Press.

Zuccaro, P. C. (2007) *Statistical Alchemy—The Use of Factor Scores in Linear Regression.* <http://www.esq.uqam.ca/recherche/document/>

Comments

This is an important paper on the role of technological inputs on output differential of four major crops i.e., wheat, rice, cotton and sugarcane. The author made a good attempt to use principal component factors' method to identify sets of variables which explain major part of the variation out of total variance in output. This is a multivariate technique where diversified variables are involved with interdependence in multiple dimensions that need to be converged into few comprehensive dimensions. The method transforms a number of possibly correlated variables into a smaller number of uncorrelated variables called principal components.

The author constructed different indices for each of the selected districts. These indices are Crop Output Index (COI), Power Resource Index (PRI), Technological Capital Index (TCI), Land Crop Composition Index (LCCI), Water Resource Index (WRI), Bio-Chemical Index (BCI), and Infrastructural Development Index (IDI). While author analyses the contribution of different input indices in crop output index through a graphical approach, it is quite surprising that these indices have not been reported in the paper. The author should report these indices in a table so that one understand and compare the changes in different indices over time.

While explaining results, author argued an increased potential of reduction in disguised unemployment because displaced labour mostly tends to get employment in other sectors or non-farm agricultural. The author should also recognise that this may put pressure on the wages in the non-farm sector which is one of the explanations of higher poverty incidence in this sector compared to farm sector.

While explaining the growth in different indices, author should also report whether he is referring to a particular phase of growth or the whole period. In district DG Khan that in the final phase biochemical index may be responsible for significant decline in crop output index. But the fact is that both BCI and TCI were responsible. Similarly in Gujrat the crop out index followed the growth patterns of TCI not BCI as mentioned by author. One of the limitations of the data is that rainfall data for selected stations on one time basis has been replicated over the selected time phases in other districts. This is important as it may not capture the variation in crop output index due to differences in rainfall in different districts. In addition, author should discuss the conference theme and try to link the paper with theme.

Talat Anwar

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Islamabad.