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Input Growth, Total Factor Productivity and Its Components in Punjab Agriculture: District-wise Analysis

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Punjab agriculture made exemplary progress after the introduction of high-yielding varieties (HYVs) of wheat during the sixties and rice during the seventies. However, starting perhaps with the late 1980s and definitely from the beginning of 1990s, the growth in agriculture has plateaued. The average productivity of rice increased from only 4.5 t ha^{-1} in 1981-82 to a record level of 5.3 t ha^{-1} in 1987-88, not yet surpassed since then, the closest reaching to 4.73 t ha^{-1} in 1998-99. The compound growth rate (CGR) of rice productivity in the 1980s was 1.27 per cent, which became even negative at -0.04 per cent in the 1990s. Wheat showed exemplary increase in productivity from 2.73 t ha^{-1} in 1980-81 to 4.33 t ha^{-1} in 1987-88 with a compound growth rate of 3 per cent in the 1980s, which also slowed down to 1.45 per cent in the 1990s (Annexure 1). These achievements have been possible through significantly positive trends in input use (Table 1). The input growth includes intensive use of land, i.e., cropping intensity increased from 161 during 1960-61 to 185 during 1998-99. Irrigation facilities increased the irrigated area from 81 per cent to 95 per cent in the same period. These developments were possible mainly through higher level of mechanisation in terms of number of tractors and tubewells (diesel and electric). But all these developments have led to a stage where Punjab economy finds itself at the crossroads. The growth rate is down from more than 5 per cent in 1980s to just about 2 per cent in the 1990s.

TABLE 1. AGRICULTURE INPUT-USE IN PUNJAB, 1980-81 TO 1998-99

Year	Cropping intensity	Per cent Irrigated area	Tube wells (lakhs)		Tractors (lakhs)	Fertilisers (kg/ha)
			Diesel	Electric		
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1980-81	161	81	3.20	2.80	1.19	113
1985-86	171	88	2.21	4.41	2.09	153
1989-90	176	93	2.00	5.65	2.69	155
1995-96	186	95	1.75	7.00	3.72	164
1998-99	185	95	1.70	7.45	4.12	176

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DECLINING TREND IN TFP GROWTH

The Green Revolution has in fact been a grain revolution with high opportunity costs/input use. These include over-exploitation of natural resources, ecological degradation and imbalances, environmental pollution, etc. Above all, the total factor productivity (TFP), which is the real measure of economic efficiency achieved over time on account of the farmer's rationality in resource use and as a follow up of the economic policies and environment, has been reported by many studies as declining in Punjab (Table 2). Kumar *et al.* (1999) reported that TFP declined from 3.2 per cent

TABLE 2. TFP GROWTH IN PUNJAB AGRICULTURE

Author(s) (1)	Period (2)	Crop (3)	TFP growth (4)	Comments (5)
Janaiah and Hossain (2000)	1970-82	Rice	0.79	Decelerating
		Wheat	0.82	
	1981-83	Rice	0.38	Decelerating
		Wheat	0.76	
Kumar and Mittal (1999)	1976-95	Rice	1.44	-
		Wheat	1.33	-
Rinkir Murgai (2000)	1966-74	Agriculture	4.00	Decelerating
	1975-85	Agriculture	2.91	
	1986-94	Agriculture	2.22	
Singh and Hossain (2002)	1982-89	Rice	1.51	Decelerating
	1990-97	Rice	-1.77	
	1982-89	Wheat	2.13	Decelerating
	1990-97	Wheat	1.24	
Kumar *et al.*	1976-85	Agriculture	3.20	Decelerating
	1986-92	Agriculture	0.80	
Dhillon and Ali (2002)	1978-86	Agriculture	7.41	Decelerating
	1987-95	Agriculture	1.25	
Singh, Karam (2003)	1981-89	Agriculture	1.55	Decelerating
	1990-96	Agriculture	0.05	

in 1976-85 to 0.8 per cent in 1986-92. Attributing TFP growth to technical progress, Janaiah and Hossain (2000) found a decelerating trend in TFP growth for rice in the highly productive rice-wheat system of northern India. Murgai (2000) cautioned that the low TFP growth in Punjab agriculture during the Green Revolution was due to the excessive increase in inputs. Singh (2001) estimated fast paced growth in input use in rice and wheat crops in Punjab. It increased from 0.26 per cent and 0.57 per cent during 1982-83 to 1989-90 (period I) to 0.34 per cent and 1.41 per cent during period 1990-91 to 1996-97 (period II) for rice and wheat respectively. Output growth declined over period for both the crops resulting in serious decline in growth of TFP from 1.51 per cent in period I to - 1.77 per cent in period II for rice and from 2.13 per cent in period I to 1.24 per cent in period II for wheat. Dhillon and Ali (2002) observed significant growth of TFP during 1978-86 of 7.41 per cent, which declined sharply to 1.25 per cent during 1987-95. Singh (2003) also observed a decline in TFP in Punjab agriculture from 1.55 per cent during 1981-89 to 0.05 per cent during 1990-96. Considering the existing situation of declining TFP growth in the highly

productive State of Punjab, it becomes imperative to study these changes at the regional level and its components for Punjab agriculture particularly since the 1980s. In this paper an attempt has been made: *(i)* to decompose the output growth into input growth and total factor productivity district-wise, and (ii) further to decompose the TFP into technical efficiency and technological change.

SOURCES OF OUTPUT GROWTH: METHODOLOGICAL ISSUES

An evaluation of agricultural growth performance can be made in several ways. One important method is to identify the sources of output growth so as to gauge whether it is due to increase in inputs, increase in input use efficiency, or improvements in the existing technology or introduction of new technology. Total factor productivity which is defined as growth in output which is not explained by input growth but a combined result of technical progress and technical efficiency or the efficiency with which factors are used, given the technical progress, to produce output (Fan, 1991). The existing studies on TFP in Indian agriculture have not made this distinction in their analysis (Rosegrant and Evenson, 1992; Dholakia and Dholakia 1993; Kumar and Rosegrant, 1994). To overcome this, Kalirajan *et al.*, (1996) developed a procedure to distinguish the increment in total factor productivity that occurs from technical progress from that which results from improved technical efficiency in the application of already established technology (Correlated with the level of human capital development). Thus TFP growth comprised two components: technical efficiency and technical changes. Kalirajan *et al.* (1996) estimated the technical efficiency in production using the stochastic production function of Cobb-Douglas type. A large number of studies are available on the use of stochastic production function for the measurement of technical efficiency in production (Farrell, 1957; Aigner *et al.*, 1977; Meeusen and Van den Broeck 1977). Unlike these methods, Kalirajan *et al.* estimated technical change as a shift in the production frontiers distinguishing from improvement in technical efficiency and treated the total input growth as the residual. In this approach the technical progress is considered to be non-neutral.

Source of Data and Methodology

District-wise data were used to study the sources of output growth in Punjab agriculture from twelve districts covering the period 1980-81 to 1998-99. Presently Punjab State is divided into 17 districts as five new districts were demarcated in the State during the period 1991-92 to 1995-96. To make the comparison feasible, these districts were merged with the parent districts to form 12 original districts. As some of the districts were formed by extracting area from more than one parent districts, the data relating to different variables related to these districts were merged into the parent districts according to the ratio of net sown area extracted (Annexure 2). The

data on variables included in this study were taken from the *Statistical Abstracts of Punjab*, Government of Punjab, various issues.

The stochastic frontier production function of the Cobb-Douglas type was specified for the study. Using time specific dummies, D to account for inter-year differences the function is represented in logarithmic form as follows:

$$\ln Y_{it} = \alpha_{1it} + \sum_{J=2}^{T} \gamma_{ji} D_{ji} + \sum_{k=1}^{k} {}_{kit} \ln X_{kit}$$

i = 1.....12, t = 1980-81, ...1998-99, k = 1..... 4, Djit= 1 if J= t and zero otherwise.

where $\alpha_{1it} = \alpha_1 + u_{li} + v_{lt}$ where u_{li} and v_{lt} are statistical error terms associated with individual districts and time respectively; $D_{ji} = 1$ if j = t and zero otherwise; and Y_{it} is the output level of the i-th district in period t; X_{kit} is the level of the k-th input used by i-th district in period t; α_{li} is the intercept term for the i-th district; α_{ki} is the actual response of the output to the method of application of the k-th input by the i-th district; γ_{ji} accounts for inter-year differences in production of the i-th district.

The dependent variable (Y) was aggregate agricultural output computed by aggregating the value of different crops at 1980-81 post-harvest prices. These crops includes maize, cotton, groundnut, rice, jowar, bajra, sugarcane, potato, wheat, grain, barley, rapeseed and mustard, linseed, sesamum, mash, moong and massar. There is a little under-estimation in this variable because of non-availability of data on the production of vegetables and fruits at the district level. Moreover the area under the general crops considered in this study was more than 90 per cent of the total cropped area in the state. The following independent variables were considered for the study.

X_1: Land refers to net area sown in thousand hectares.

X_2: Labour (in thousand workers), the data were available for male and female agricultural workers including cultivators for 1980-81 and 1990-91 census. Female workers availability was converted into male equivalent using the usual conversion factor of one female worker equal to 0.67 male workers. The growth rates in the number of workers for each district were estimated separately. These growth rates were used for interpolation of the number of workers between these years and for extrapolation for some other years wherever required. It needs to be mentioned here that the total agricultural labour available was considered as actual labour used in agriculture.

X_3: Fertiliser (in thousand kgs of nutrients). The data regarding consumption of fertiliser (N, P, K) were obtained from *Statistical Abstracts of Punjab*, Government of Punjab. This variable is assumed to be a fair substitute for land because land is a fixed magnitude in horizontal direction over a short period and fertiliser use expands

the land in vertical direction through intensive cultivation (Heady, 1963; Kahlon and Singh, 1976; Singh *et al.*, 1997).

X_4: Machinery (in horse power unit). Machinery includes tractors and electric motors measured as total horsepower unit. It is worked out by multiplying the number of tractors in each district with 35 plus the number of electric motor multiplying by 5. Tractor and electric motors are assumed to be the main component of machinery or these are complementary/supplementary to other machinery used on the farm.

The per cent of area irrigated was also included as an independent variable in the study but the coefficient was not found explanatory, which might be due to the low variability observed in this variable district wise and over the period and thus excluded from the analysis.

Using computer programme[1] the stochastic varying coefficient frontier is estimated from the pooled data for the two time periods, viz., 1980-81 to 1989-90 and 1990-91 to 1997-99. Then the decomposition of total output growth into input growth, technical progress and technical efficiency improvement has been done following Kalirajan approach (for details see Kalirajan and Shand, 1997).

RESULTS AND DISCUSSION

The estimated coefficients of frontier production function are given in Table 3. All the independent variables have positive coefficients during the eighties (Period-I)

TABLE 3. COEFFICIENTS OF STOCHASTIC FRONTIER PRODUCTION FUNCTION

Variable	Period - I 1980-81 to 1989-90	Period – II 1990-91 to 1998-99
(1)	(2)	(3)
Intercept	-0.1929	0.3264
	(-0.1022	(0.1103)
Net area sown	0.5658	0.8773
	(3.3361)**	(2.8263)*
Labour	0.2429	-0.2626
	(1.4570)	(-0.8466)
Machinery	0.2594	0.6809
	(3.9882)**	(4.7282)**
Fertiliser	0.0823	-0.2928
	(1.3164)	(-1.8222)
Σ_{bi}	1.1504	0.9988
Sigma squared	0.0450	0.0702
	(2.3794)	(2.3568)
Gamma	0.9423	0.7743
	(36.3974)	(7.5493)
Log-likelihood function	163.8191	56.3750

Figures in parentheses are t-values.
*** and * Significant at 1 and 5 per cent level, respectively.

whereas the coefficient of labour and fertiliser were negative during the nineties (Period-II). This gives an indication that the use of human labour and fertiliser were

in excess in Period-II. The coefficients of net area sown and machinery were significant at one per cent indicating the scope of increasing the value productivity by increasing the level of these inputs. The coefficient of machinery increased from 0.26 in 1980s to 0.68 in 1990s, which suggests increasing role of mechanisation in Punjab agriculture, which would have demanded the decline in human labour input in agriculture, but its (labour's) coefficient turning negative (-0.26) in the nineties suggests the increasing phenomenon of disguised unemployment in Punjab agriculture having taken roots in the nineties. Certainly this would have its own toll on the change in total factor productivity in Punjab agriculture over time. The sum of the estimated coefficients of independent variables (Σ_{bi} returns to scale) declined from 1.1504 to 0.9988. All the time dummy coefficients were positive during the eighties (Annexure 3). These were significant at five per cent level for the year 1984-85, 1985-86 and 1989-90 (Period-I). During the nineties the time dummy coefficient were negative for the years 1992-93, 1995-96, 1996-97 and 1997-98 (Period-II). All the coefficients were non-significant during this period.

Progressive Agriculture Became an Inefficient Agriculture

An examination of the contribution of TFP growth to total output growth between different district of the Punjab State shows that ten districts out of twelve have positive contribution of TFP growth during the eighties (1980-81 to 1989-90) (Table 4). Bathinda recorded the best performance with 50 per cent growth. Ferozepur, Patiala and Jalandhar districts followed closely with over 40 per cent TFP growth). A further four districts achieved between 30 and 40 per cent growth and the other two have TFP growth between 10 and 30 per cent. Roopnagar and Hoshiarpur had negative TFP growth to the tune of 20 and 6 per cent respectively. During the nineties (1990-91 to 1998-99) when the sustainability of productivity was the main

TABLE 4. CONTRIBUTION OF TOTAL FACTOR PRODUCTIVITY GROWTH IN OUTPUT GROWTH IN PUNJAB AGRICULTURE

(per cent)

District	1980-89	1990-99
(1)	(2)	(3)
Amritsar	32.80	7.88
Bathinda	50.00	-27.78
Faridkot	39.14	-9.46
Ferozepur	47.09	53.33
Gurdaspur	19.31	61.97
Hoshiarpur	-6.64	-67.48
Jalandhar	41.47	46.63
Kapurthala	10.60	33.44
Ludhiana	33.93	-102.80
Patiala	41.63	-25.52
Roopnagar	-20.00	79.56
Sangrur	38.42	-63.89

issue, TFP growth showed inconsistent performance among different districts. There were six districts whose TFP growth became negative. Even for the district (Bathinda) whose TFP growth was the highest during the eighties, it came to be negative in the nineties. At the same time there were five districts whose performance improved during the nineties. Roopnagar district improved a lot over this period from –20 per cent to about 80 per cent growth in TFP. There were substantial changes noted in the contribution of TFP growth over a period among different districts of the State. There was an improvement in the contribution of TFP growth in some districts as well as deterioration in its contribution to the productivity in other districts. Overall there were substantial diminished performances in the contribution of total factor productivity growth during the nineties.

To explore the changing trend of TFP growth among different districts of the state, three components of output growth, viz., input growth, technical change and change in technical efficiency were examined for two periods (Table 5).

TABLE 5. DECOMPOSITION OF OUTPUT GROWTH IN PUNJAB AGRICULTURE, 1980-89 AND 1990-99

(per cent)

District	1980-89			1990-99		
	Output growth due			Output growth due to		
	Input growth	Technology change	Technical efficiency	Input growth	Technology change	Technical efficiency
(1)	(2)	(3)	(4)	(5)	(6)	(7)
Amritsar	67.20	24.34	8.46	92.12*	67.49	-59.61
Bathinda	50.00	26.54	23.46	127.78*	63.42	-91.20
Faridkot	60.86	25.84	13.30	109.46*	56.38	-65.84
Ferozepur	52.91	25.09	22.00	46.67	91.33	-38.00
Gurdaspur	80.69	34.16	-14.85	38.03	48.24	13.73
Hoshiarpur	106.64*	50.92	-57.56	167.48	111.38	-178.86
Jalandhar	58.53	36.22	5.25	53.36	61.44	-14.80
Kapurthala	89.40	33.25	-22.65	66.56	44.05	-10.61
Ludhiana	66.07	35.20	-1.27	202.80	128.04	-230.84
Patiala	58.37	34.00	7.63	125.52*	94.48	-120.00
Roopnagar	120.00*	60.00	-80.00	20.44	7.06	72.50
Sangrur	61.58	23.67	14.75	163.89*	126.85	-190.74

* Districts having negative TFP.

The analysis showed that during the eighties more than 50 per cent contribution to the output growth was due to input growth in all the ten districts where TFP growth was positive leaving two districts, namely, Hoshiarpur and Roopnagar where TFP growth was negative. The contribution of new technology was between 23 per cent to 36 per cent for all the districts having positive TFP growth. Technical efficiency was negative for three districts and varied between 1.27 to 14.85 per cent. Technical efficiency for Hoshiarpur and Roopnagar districts was negative to the tune of 57 and 80 per cent resulting into negative TFP during eighties. During the nineties six districts have negative TFP growth due to negative technical efficiency change. During this period there were 10 districts where technical efficiency was negative and only two districts, namely, Gurdaspur and Roopnagar have positive technical

efficiency change. The per cent contribution of input growth was higher during the nineties in Gurdaspur district.

The analysis confirms that during the eighties output growth came increasingly from input growth. Excluding those districts with negative TFP growth, input growth contributed more than 50 per cent in all the districts (ranged between 50 to 90 per cent) and it further increased during the nineties (ranged between 20 to 200 per cent). The contribution of technology change was positive during both the periods even higher during the nineties. During the eighties technical efficiency was negative for five districts and ranged between 1.27 (Ludhiana) per cent to 80.00 per cent (Roopnagar), but the situation worsened during the nineties when technical efficiency became negative for 10 districts out of twelve districts and ranged between 13.73 per cent (Gurdaspur) to 230.84 per cent (Ludhiana) indicating that the number of districts increased over period where the increase in output was not commensurate with the given set of inputs. Thus, increasing inefficiency is the main factor responsible for declining/negative TFP in Punjab agriculture in spite of increase in input growth and positive technical change, which calls for further detailed studies on identifying the underlying factors for increasing inefficiencies in production in Punjab agriculture. It places a great challenge for policy makers, extension workers and researchers to bring the farmers to precision farming. This puts great onus on research workers and policy makers to fine-tune both top down and bottom up flow of information for generation, promotion and evaluation of specific technologies.

CONCLUSIONS

It can be concluded from the above discussion that total factor productivity has shown dismal performance in Punjab agriculture, since the eighties. It was negative in two districts during the eighties and in six districts during the nineties. The findings that output growth in all the districts and both in 1980s and 1990s has been quite significantly due to technological change having been adopted by the farmers but the contribution of technical efficiency was much lower and even negative in five districts during the 1980s and as many as 10 districts in the 1990s suggests that the resource adjustments required for the adoption of technological changes have not been forthcoming. That is to say the more progressive the agriculture, the more inefficient it has become. This puts great onus on the research workers and policy makers to fine-tune both top down and bottom up flow of information for generation, promotion and evaluation of specific technologies.

NOTE

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ANNEXURE 1. COMPOUND GROWTH RATE OF AREA, PRODUCTION AND YIELD OF RICE AND WHEAT IN PUNJAB

Crop	1980-81 to 1989-90	1990-91 to 1989-99
(1)	(2)	(3)
Rice		
Area	5.47	2.15
Production	6.74	2.11
Yield	1.27	-0.04
Wheat		
Area	1.26	0.13
Production	4.30	1.56
Yield	3.00	1.45

ANNEXURE 2. COEFFICIENTS USED TO STANDARDISE DATA FOR THE ORIGINAL 12 DISTRICTS

S. No.	District	Original district	Proportion of the different variables of the new district merged with the original district
(1)	(2)	(3)	(4)
1.	Nawan Shahar	Jalandhar	0.60
		Hoshiarpur	0.40
2.	Mukatsar	Faridkot	1.00
3.	Moga	Faridkot	1.00
4.	Mansa	Bathinda	1.00
5.	Fatehgarh Sahib	Patiala	0.83
		Ludhiana	0.17

ANNEXURE 3. COEFFICIENTS FOR TIME DUMMY

	Period – I			Period - II	
Year	Coefficient	t-value	Year	Coefficient	t-value
(1)	(2)	(3)	(4)	(5)	(6)
Intercept	-0.1929	-0.1822	Intercept	0.3264	0.1103
1981-82	0.0268	1.1638	1991-92	0.0073	0.1433
1982-83	0.0258	0.9752	1992-93	-0.0158	-0.2796
1983-84	0.0363	1.1718	1993-94	0.0576	0.9621
1984-85	0.0769	2.1909	1994-95	0.0420	0.6818
1985-86	0.1132	2.9422	1995-96	-0.0535	-0.7821
1986-87	0.0474	1.1080	1996-97	-0.0407	-0.5562
1987-88	0.0836	1.7964	1997-98	-0.0829	-1.1195
1988-89	0.0485	0.9875	1998-99	0.1100	1.4078
1989-90	0.1243	2.4671			

REFERENCES

Aigner, D.J., C.A.K. Lovell and P. Schmidt (1977), "Formulation of Stochastic Frontier Production Function Models", *Journal of Econometrics*, Vol. 6, No. 1, July, pp. 21-37.

Dholakia, R.H. and B. H. Dholakia (1993), "Growth of Total Factor Productivity in Indian Agriculture", *The Indian Economic Review*, Vol. 28, No. 1, January-June, pp. 25-40.

Fan, S.(1991), "Effects of Technological Change and Institutional Reform on Production Growth in Chinese Agriculture". *American Journal of Agricultural Economics*, Vol.73, pp. 266-275.

Farrell, M. J. (1957), "The Measurement of Productive Efficiency", *Journal of Royal Statistical Society*, Part III, Vol. 120, pp. 253-267.

Kalirajan, K. P., M. B. Obwona and S. Zhao (1996), "A Decomposition of Total Factor Productivity Growth: The Case of Chinese Agricultural Growth Before and After Reforms", *American Journal of Agricultural Economics*, Vol. 78, pp. 331-338.

Kalirajan, K. P. and R. T. Shand (1997), "Sources of Output Growth in Indian Agriculture", *Indian Journal of Agricultural Economics*, Vol. 52, No. 4, October-December, pp. 693-706.

Kumar, P. and M.W. Rosegrant (1994), "Productivity and Sources of Growth for Rice in India", *Economic and Political Weekly*, Vol. 29, No. 53, December 31, pp. A-183-A-188.

Meeusen, W. and J.van den Broeck (1977), "Efficiency Estimation from Cobb-Douglas Production Functions with Compose Error", *International Economic Review*, Vol. 18, pp. 435-444.

Rosegrant, M.W. and R.W. Evenson (1992), "Agricultural Productivity and Sources of Growth in South Asia", *American Journal of Agricultural Economics*, Vol. 74, No. 3, August, pp. 757-761.

Singh, Karam (2003), *Punjab Agricultural Policy Review*, Report for the World Bank, New Delhi.

Singh, Karam, Milkho Kaur and Manjeet Kaur (1997), "Technological Changes, Institutional Developments and Aggregate Agricultural Production Function for Punjab", *Journal of Agricultural Development and Policy*, Vol.9, No. 2, pp. 23-48.

Murgai, R. (2000), "The Green Revolution and the Productivity Paradox: Evidence from Indian Punjab", *Agricultural Economics*, Vol. 25, Nos. 2&3, pp. 199-210.

Singh, J. and M. Hossain (2002), "Total Factor Productivity Analysis and Components in a High Potential Rice-Wheat System: A Case Study of Indian Punjab", in M. Hossain and Bhardy (Eds.) (2002), *Development in the Asian Rice Economy*, International Rice Research Institute, The Philippines.