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Distinguished Lecture

Agricultural Productivity Growth in Pakistan and India: A Comparative Analysis*

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INTRODUCTION

Estimates of partial factor productivity growth for rice and wheat in India and Pakistan have shown relatively rapid growth in yields per hectare since adoption of modern rice and wheat varieties began in the mid-to-late 1960s [Byerlee (1990); Rosegrant (1991)]. Yields per hectare for rice and wheat grew slowly prior to the green revolution, then increased dramatically (Table 1). In Pakistan, yield growth from 1965 to 1975 was particularly rapid, but declined sharply after that. Indian yields grew more slowly than in Pakistan in the early green revolution period, but higher yield growth was sustained in India after 1975.

Table 1

Annual Growth Rates in Partial Factor Productivity (Yield per Hectare), Rice and Wheat

	Annual Growth Rate, by Period (%)			
	1956–85	1956–65	1965–75	1975–85
India				
Rice	1.74	0.72	1.71	2.51
Wheat	3.11	0.93	4.29	3.56
Pakistan				
Rice	2.15	1.00	4.13	0.73
Wheat	2.60	0.70	4.53	2.02

However, while partial factor productivity growth for rice and wheat in India and Pakistan has been extensively analysed, there is relatively little understanding of total factor productivity growth and the sources of productivity growth in the

*Owing to unavoidable circumstances, the second discussant's comments on this paper have not been received.

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crops sector, or of the relative contribution to output growth from productivity growth compared to increased factor use.

This paper assesses total factor productivity (TFP) growth in India and Pakistan, and in the Indian and Pakistani Punjabs, examines the sources of productivity growth, and estimates the rates of return to public investments in research and extension. Is the pattern of TFP growth similar to that of partial factor productivity growth? What explains the differences in TFP growth between India and Pakistan? The paper first describes the methodology for estimation of TFP, decomposition of TFP, and estimation of rates of return to public investments, describes the data, and presents results and policy implications.

METHODOLOGY AND DATA

Estimation of Total Factor Productivity

Analysis of total factor productivity attempts to measure the amount of increase in total output which is not accounted for by increases in total inputs. The total factor productivity index is computed as the ratio of an index of aggregate output to an index of aggregate inputs. Growth in TFP is therefore the growth in total output less the growth rate in total inputs. For India, Tornqvist-Theil TFP indices are computed for 271 districts covering 13 states in India, 1956–87. For Pakistan, TFP indices are computed for 35 districts in three states, 1955–85. Mean results are reported for India, Pakistan, and the two Punjabs, and trends in TFP are compared across countries and regions.

Expressed in logarithmic form, the Tornqvist-Theil TFP index is

$$ln(TFP_t / TFP_{t-1}) = \tfrac{1}{2} \sum_j (R_{jt} + R_{jt-1}) \, ln\,(Q_{jt} / Q_{jt-1})$$
$$- \tfrac{1}{2} \sum_j (S_{it} + S_{it-1}) \, ln\,(X_{it} / X_{it-1}) \quad \ldots \quad \ldots \quad \ldots \quad (1)$$

where R_{jt} is the share of output j in revenues, Q_{jt} is output j, S_{it} is the share of input i in total input cost, and X_{it} is input i, all in period t. Specifying the index to equal 100 in a particular year and accumulating the measure based on Equation (1) provides the TFP index.

The Tornqvist-Theil index is a superlative index which is exact for the linear homogeneous translog production function [Diewert (1976)]. A further advantage of the Tornqvist-Theil index is that it accounts for changes in quality of inputs. Because current factor prices are used in constructing the weights, quality improvements in inputs are incorporated, to the extent that these are reflected in higher wage and rental rates [Capalbo and Vo (1988)].

The Tornqvist-Theil index provides consistent aggregation of inputs and outputs under the assumptions of competitive behaviour, constant returns to scale, Hicks-neutral technical change, and input-output separability. However, Caves, Christensen and Diewert (1982) have shown that Tornqvist-Theil indices are also superlative under very general production structures, i.e., nonhomogeneous and nonconstant returns to scale, so they should provide consistent aggregation across a range of production structures [Antle and Capalbo (1988)].

Five major crops (rice, wheat, sorghum, pearl millet, and maize) and ten minor crops are included in the output index for India. Crops for Pakistan include wheat, rice, cotton, sugar, millet, maize, sorghum, gram, rapeseed, tobacco, barley, and mungbeans. Farm prices are used to aggregate the outputs. Inputs included in the input index are land, irrigation, labour, animal labour, tractors, and fertiliser. Inputs are aggregated using farm rental prices, with differentiation of rental prices for irrigated and non-irrigated land. The value of publicly funded surface irrigation as an input is therefore approximated by its effect on land prices. For India, the value of tubewell irrigation is directly incorporated in the input index through the rental price on tubewell investment, but this procedure was not followed for Pakistan, due to lack of time series data on tubewell prices.

Total Factor Productivity Decomposition

Increases in productivity can be induced by investments in research, extension, human capital, and infrastructure. As an input into public investment decisions, it is useful to understand the relative importance of these productivity-enhancing investments in determining productivity growth. The second part of the analysis is therefore to estimate the determinants of TFP and, based on these estimates, to compute the marginal rate of return to productivity-enhancing public investments.

In order to assess the determinants of TFP, the TFP index was estimated as a function of variables representing investments in research, extension, human capital, and infrastructure. Estimation was undertaken using a fixed effects approach for the pooled cross section time series district level data sets, with corrections for serial correlation and heteroskedasticity [Kmenta (1981)]. The total number of observations in the data set is 8,672 for India and 1,085 for Pakistan.

TFP decomposition specifications relate TFP growth to changes in technology, infrastructure, and human capital. For technology, this requires that variables based on past research and extension programmes be developed. In general, there are no strong functional form implications to be derived from optimisation theory that can be imposed on this specification unless there is reason to believe that governments actually choose TFP growth-producing projects in an optimising fashion. The TFP decomposition equations are specified here in double-log form.

For variables such as research and extension, the variable definitions must reflect the possible long lags in impact of an expenditures in previous time periods. The appropriate research variable should, therefore, reflect a cumulation in its timing weights. In addition, it should reflect technological spill-in from outside the district.

The general form for the research variable is:

$$R_{ik}^{*} = \sum_{j} G_{ij} \sum_{k} W_{ik} r_{ijt-k} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (2)$$

where r_{ijt-k} is research investment in commodity i, region j, in period $t-k$. The research stock is thus based on cumulated past investments and weighted by two sets of weights. The first set, G_{ij}, are spill-in weights measuring the degree to which research conducted in location j is productive in location i relative to the productivity of research conducted in location i. These weights are based on agro-climatic regions. The second set of weights are time-shape weights, W_{ik}. These weights reflect the lag between research expenditure and the ultimate productivity impact. They can also reflect real depreciation of research impacts. These weights are estimated based on minimising the mean square error of the fit of the TFP decomposition equations [see Azam, Bloom and Evenson (1991) for a more detailed description].

There is also a deflation issue that must be dealt with in cases where research variables must be aggregated across commodities (i.e., over i). For cases where the dependent variable is cumulated TFP, each commodity research variable could be included as a regressor. However, this often results in a high degree of multi-collinearity, so aggregation is desirable. The aggregation

$$R_{t}^{*} = \sum_{i} S_{i} \quad R_{is}^{*} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (3)$$

where S_i is the share of commodity i in value of crop output, is reasonable if one presumes no spill-over between research programmes, that is to say, research on commodity j does not enhance productivity for commodity i.

The independent variables utilised in the analysis for India include the following: MKTS, the number of regulated markets; NIANCA, the ratio of net irrigated area to net cropped area; RELWAGE, the ratio of farm wages to annual earnings of non-farm workers; LITERACY, the proportion of rural males who are literate; EXT, lagged extension expenditures per farm; RES, the stock of research, computed as a weighted distributed lag of research expenditures as described above; HYV, the proportion of area under modern crop varieties, weighted by crop shares; YEARRAIN, JUNERAIN, and JUAURAIN, which are annual, June, and July/August rainfall, the latter two measures representing important monsoon periods; YEAR, which is a linear trend variable; RELPRICE, the ratio of wholesale price to farm price; and DOMINV and FORINV, the sum, respectively, of cumulated domestic and foreign patented inventions of agricultural implements, weighted by tractor share in inputs, plus cumulated inventions for fertiliser, seed, and chemicals, weighted by the fertiliser share in inputs; REXDOM, which is a multiplicative interaction variable between public research and extension and domestic private inventions; and EXTFOR, which is a multiplicative interaction variable between public extension and private foreign inventions. Finally, dummy variables are included for agroclimatic zone. For detailed descriptions of variables and data sources, see McKinsey, Evenson and Judd (1991).

In the analysis undertaken for Pakistan, the following variables are utilised: APPRES, the aggregate cumulated commodity-specific research stock, based on number of research personnel, and computed as described above; RESGEN, the cumulated research stock based on expenditures that are not commodity specific; SHGRAD, the proportion of research personnel holding graduate degrees; LITERACY, the proportion of literate rural adult males; SHHYV, the proportion of wheat, rice, and cotton area planted to high-yielding varieties; MKTDIST, a measure of investment in markets, defined as the average distance for farms in a district from major market centres; FARMSIZE, the average farm size; IRRIGSH, the proportion of the cropped area under irrigation; CANALSH, the proportion of the cropped area irrigated by canal; TUBEWSH, the proportion of the cropped area irrigated by tubewells; RAIN, the level of rainfall in the primary cropping months; ROADS, the proportion of paved roads per cropped area; and POPDENSITY, the rural population per cropped area.

TFP Growth Accounting and Marginal Rates of Return to Investment

Based on the estimated parameters for the variables in the TFP decomposition equation and the growth rates for these determinants of TFP, the contribution of each of the variables to TFP growth can be shown more clearly. Finally, marginal internal rates of return to public investment in research and extension were computed from the estimated TFP decomposition equation. To compute marginal rates of return, the stream of marginal output generated from the investments was first computed utilising the estimated parameters from the TFP decomposition equations and the lag structure of the public research and extension variables. Then the marginal internal rates of return were computed as the discount rate at which this stream of output has a unit value.

RESULTS

Total Factor Productivity Growth

Trends in total factor productivity in India, Bangladesh, and Pakistan are shown in Figures 1 and 2 and Table 2. In India, TFP grew relatively steadily over time, with modest variation in growth rate over periods, but with large fluctuations due to weather variation. Particularly large drops in TFP occurred in the severe drought years of 1965, 1966, and 1979. Variation in TFP around trend is due nearly entirely to variation in output, as total input use increased smoothly over time. The rate of growth in TFP in the Indian crops sector, 1956–85, was about 1 percent per annum, or about two-thirds of the rate of growth in TFP in U. S. postwar agriculture [Jorgenson and Gollop (1992)]. With total output growth increasing at 3 percent per annum, productivity growth has accounted for approximately one-third of total output growth in the Indian crops sector.

Table 2

Annual Rates of Growth in Total Factor Productivity in the Crops Sector

	Annual Growth Rate, by Period (%)			
	1956–85	1956–65	1965–75	1975–85
India	1.01	0.81	1.22	0.98
Pakistan	1.07	1.65	1.86	–0.36
Indian Punjab	1.33	1.62	1.48	0.69
Pakistani Punjab	1.06	1.42	2.13	–0.84

Note: Trends are estimated based on three-year moving averages, centered on years indicated.

Total factor productivity in the Pakistani crops sector grew at a slightly higher rate over the full period than in India, but the pattern of growth was very different. After 1975, there was an actual decline in TFP after 1975 following rapid growth during the early green revolution period (Table 2). Similar to the case for India, TFP growth accounted for about one-third of total output growth over the full period.

TFP in the Indian Punjab grew at a rate faster than India as a whole and faster than the Pakistani Punjab, at 1.33 percent over the full period. As with the national productivity growth rate for India, the growth rate in TFP for the Indian Punjab declined significantly after 1975. The Punjab in Pakistan registered strong

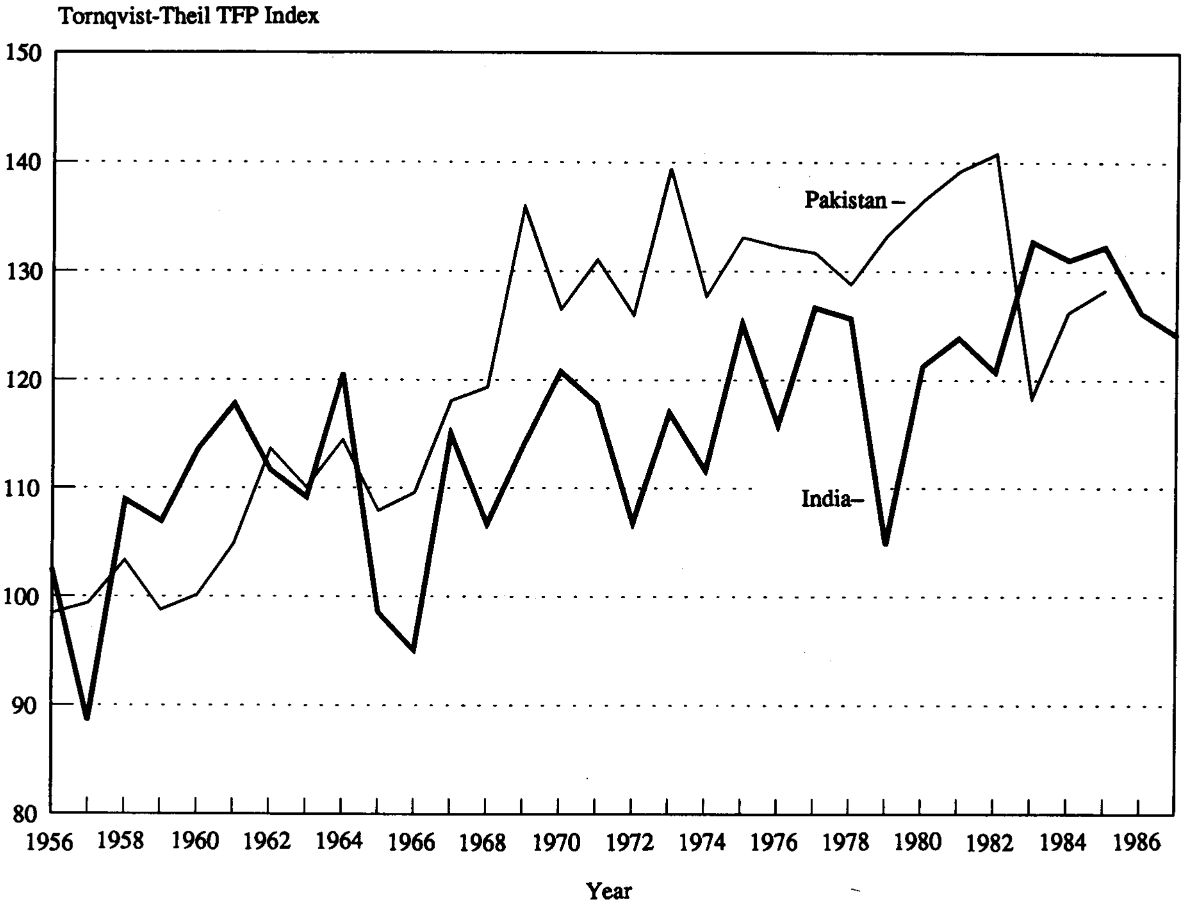

Fig. 1. **Total Factor Productivity in the Crops Sector, India and Pakistan, 1956–87.**

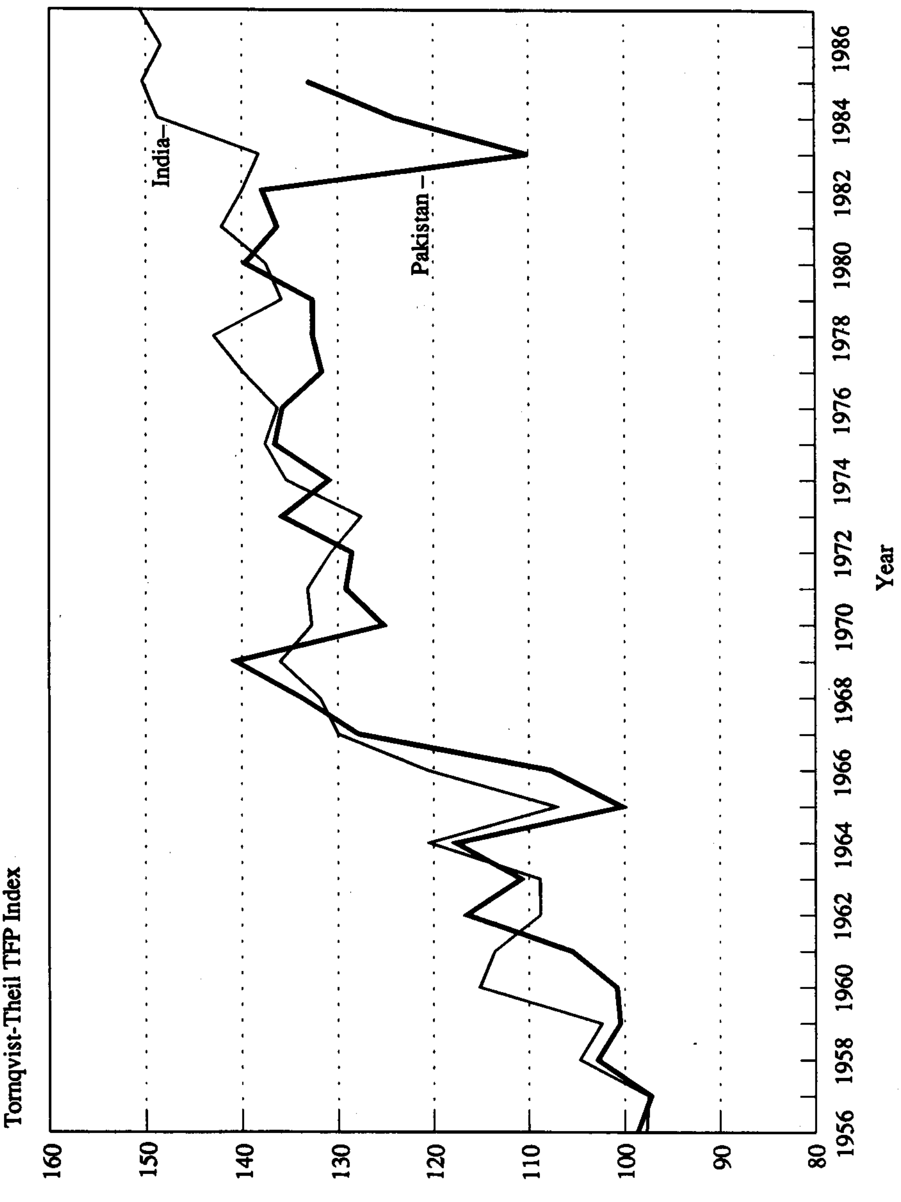

Fig. 2. Total Factor Productivity in the Crops Sector, Indian Punjab and Pakistani Punjab, 1956–87.

growth through 1975, but suffered a drop in TFP thereafter, with an annual growth rate of –0.84 in the final subperiod. The next sections of the paper examine some of the underlying causes for these different patterns of growth.

Total Factor Productivity Decomposition

The estimated parameters from the TFP decomposition equation for the crops sector in India are presented in Table 3. Estimated parameters for the agroclimatic dummy variables are not presented in the interest of brevity. The results indicate that research and extension have a highly significant impact on TFP. The stock of research, extension expenditures, domestic and foreign inventions, and adoption of modern varieties each have a statistically significant, positive impact on TFP. The results for the interaction variables (REXDOM and EXTFOR) show that public research and extension are complementary with private research.

Table 3

Total Factor Productivity Decomposition for the Crops Sector, India, 1956–87: Estimated Parameters

Variable	Parameter Estimate	Standard Error
INTERCEPT	17.053**	1.896
MKTS	0.009*	0.003
NIANCA	0.043**	0.003
RELWAGE	–0.014*	0.006
LITERACY	0.028*	0.012
EXT	0.026**	0.005
RES	0.028**	0.004
HYV	0.007**	0.001
YEARRAIN	0.011**	0.001
JUNERAIN	–0.003*	0.002
JUAURAIN	–0.003**	0.001
YEAR	–0.009**	0.001
RELPRICE	0.158**	0.008
DOMINV	0.008**	0.002
FORINV	0.022**	0.004
REXDOM	0.00005*	0.00003
EXTFOR	0.00061**	0.00017

R^2 between Observed and Predicted = 0.23

F–ratio = 89.32 Degrees of Freedom: 8,647

Note: Asterisks indicate significance levels: ** = 1 percent, * = 5 percent.
Dependent variable is the TFP index. All variables specified in logarithms.

LITERACY (0.27), IRRIGSH (0.24), SHHYV (0.13), APPRES (0.05), and RESGEN (0.02).

The importance of research and technology development in India and Pakistan is confirmed by computation of the marginal internal rates of return on public investment in research, extension, and generation of modern varieties, computed as described above. For India, the estimated rate of return to research is 63 percent, and to extension, 52 percent, indicating very high rates of return to these public investments. For Pakistan, the marginal rate of return to crop-specific research is 58 percent, to general research, 39 percent, and to generation of HYV, 51 percent.

Sources of Total Factor Productivity Growth

The TFP decomposition equations, combined with the patterns of growth of the estimated determinants of TFP, provide some insight into the different patterns of growth over time for Pakistan, India, and the two Punjabs. Tables 5 and 6 show the pattern of growth of the independent variables in the TFP decomposition equations over the full period of analysis and over three subperiods.

The pattern of growth shown in these tables helps to understand the underpinnings of the substantial total productivity growth in both India and Pakistan during the 1955/56–65 period, before the rapid spread of modern varieties. For India, this was a period of rapid growth in investment in research and extension, strong growth in literacy, and very rapid growth in inventions in agricultural implements and inputs generated by private research and investment. The same pattern was exhibited in the Indian Punjab, but with even higher growth in investment. Similarly, for Pakistan and the Pakistani Punjab, heavy investment in research and rapid improvements in human capital, as shown by improvements in literacy and share of graduate personnel in research, induced strong growth in agricultural productivity even before the rapid adoption of modern varieties.

In the early green revolution phase (1965–75), TFP growth in India was sustained by rapid adoption of modern varieties and sharp increases in irrigation investment, despite somewhat lower rates of growth in investment in extension and public and private research (Table 5). As shown in Table 6, in Pakistan and the Pakistani Punjab, TFP growth accelerated during this period due to sustained growth in irrigation development and the explosive growth in use of modern varieties, which more than offset the decline in growth of investment in research and human capital development (the latter reflected in a slowdown in the growth of literacy).

However, as the adoption of modern varieties slowed during the 1975–85 period, putting downward pressure on productivity growth, the patterns of productivity-enhancing public investment diverged in India and Pakistan. In India, invest-

Table 5

Sources of Total Factor Productivity Growth in the Indian Crops Sector, 1956–85

	India Annual Growth Rate (%)				Indian Punjab Annual Growth Rate (%)			
Variable	1956–85	1956–65	1965–75	1975–85	1956–85	1956–65	1965–75	1975–85
MKTS	3.44	3.13	3.93	3.07	6.91	5.69	4.78	9.66
NIANCA	3.42	1.00	3.87	2.30	1.96	2.01	2.69	0.86
RELWAGE	0.003	–1.30	1.43	–0.24	0.28	–0.04	1.98	–0.57
LITERACY	0.65	2.53	0.61	0.73	2.63	1.07	2.77	2.97
EXT	12.46	24.80	10.01	16.94	8.99	25.22	3.24	10.43
RES	7.34	8.76	6.34	8.95	6.34	6.94	5.48	8.62
HYV	3.06	0.00	7.19	2.23	8.83	0.00	19.26	2.15
RELPRICE	0.60	–1.38	1.97	1.09	1.63	–2.57	2.60	3.53
DOMINV	13.60	33.08	21.92	8.44	21.86	39.58	26.34	7.83
FORINV	19.40	31.72	21.48	9.84	18.88	34.96	22.60	8.60

Table 6

Sources of Total Factor Productivity Growth in the Pakistani Crops Sector, 1955–85.

Variable	Pakistan Annual Growth Rate (%)				Pakistani Punjab Annual Growth Rate (%)			
	1955–85	1955–65	1965–75	1975–85	1955–85	1955–65	1965–75	1975–85
APPRES	15.91	24.82	15.21	9.81	15.67	24.64	14.91	9.63
RESGEN	16.20	25.82	15.22	9.05	15.52	25.15	14.48	8.68
SHHYV	7.99	0.02	17.94	2.96	7.83	1.06	16.68	3.08
IRRIGSH	0.28	0.68	0.78	0.24	0.67	1.29	1.13	0.01
CANALSH	–0.72	–1.09	0.19	–0.69	–1.28	–1.33	–0.88	–0.92
TUBEWSH	13.09	28.40	9.44	2.62	12.62	26.79	9.65	2.44
SHGRAD	6.43	7.55	6.26	3.18	6.83	9.42	5.89	3.25
MKTDIST	–0.01	–0.03	0.02	–0.14	0.17	0.00	0.28	–0.29
LITERACY	3.21	4.46	3.08	2.35	3.42	4.85	2.22	2.31
ROADS	3.63	2.59	3.91	4.41	3.28	2.22	3.74	4.15
POPDEN	2.87	2.60	3.09	2.27	2.60	2.31	2.80	2.11

ment in irrigation dropped moderately, but was sufficient to sustain growth in the proportion of area irrigated, while expansion of the proportion of area irrigated in Pakistan virtually stopped. Growth in investment in public research, extension, and literacy in India actually increased relative to the previous decade. By contrast, the rate of growth in investment in research, technology, irrigation, and human capital development in Pakistan again declined sharply relative to the previous decade. Thus, while the rate of growth of TFP in India declined by only about 15 percent during 1975–85, the rate of growth of TFP in Pakistan became negative, dropping from 1.86 percent to –0.36.

Obviously, other factors have contributed to the decline in TFP in Pakistan after 1975, including government policies taxing agriculture and increasingly serious soil salinity and other environmental degradation [Azam, Bloom and Evenson (1991); David and Rosegrant (n.d.)]. It would be particularly useful to extend the analysis presented here to incorporate the impact of environmental degradation on total factor productivity growth. Nevertheless, the evidence presented here shows the strong impact of investment in research, technology, and human capital development on long term productivity growth.

CONCLUSIONS

This paper has assessed the sources of TFP growth in the crops sector in Pakistan and India, has utilised this analysis to explain the patterns of growth in TFP, and has estimated the rates of return to public investments in research and extension. TFP growth explains about one-third of total output growth in the crops sector of each of the countries, from 1956 to 1985. The main sources of productivity growth have been public research and extension, adoption of modern varieties, expansion of irrigated area, improvement in human capital through expansion of literacy, and private research (the latter in India). The spill-over benefit from private research is substantial, indicating that private firms capture only part of the real value of improved inputs through higher prices. The rates of return to public research and extension are high, showing the continued profitability of public investment in agricultural research and extension, and strongly indicating that both governments are underinvesting in research and extension.

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Comments on
"Agricultural Productivity Growth in Pakistan and India: A Comparative Analysis"

I have 3 areas on which I want to offer my opinion. These are on:

(1) Theoretical conceptualisation, (2) Empirical methodology, and (3) Analytical interpretation of the results.

Theoretical Conceptualisation

Total Factor Productivity (TFP) is meant to separate the growth of inputs from the productivity of those inputs. We have therefore:

TFP growth = Output growth – Input growth

So we are concerned with a quantum growth of output. Now Eulers theorem demands product exhaustion–exhaustion of all of this output. This implies especially for a growth accounting exercise like this, that we account for all possible sources of growth of output. Therefore let us examine all possible sources of TFP. For this, we have to examine sources of increase of efficiency of the output, which leave the value of the input constant.

We have the usual two factors, capital productivity and labour productivity. Then because of agriculture we will use the third Ricardian factor of land productivity. Finally we have organisational productivity.

(i) Capital productivity is important because TFP can increase because of better machines of constant value. This is Harrodian technical change, where the capital output ratio drops.

(ii) Labour productivity is important because of change in human capital (HK). HK itself has two sources of growth. One which the authors emphasise is information. But the second is what the authors omit, but is very important, nutrition. Labour effort increases with nutrition.

(iii) Land productivity is important because of changes in soil fertility. In Pakistan and India there is a major problem of salinity, which the authors acknowledge needs to be incorporated in principle, but omit. We also need to acknowledge at least in principle, the weather here. Although this is difficult to model because of the notorious butterfly effect. A butterfly in Manhattan can delays the monsoons in the Himalayas. Why it is important, is because it makes profit maximising algorithms quite irrational as Lipton has shown. It also makes production functions difficult to fit for agriculture as Bharadwaj showed.

(iv) Organisational productivity is important but complex, because these managerial efficiencies can move, over historical time periods in the opposite direction to the role of HK assumed by the authors. Now systemic efficiencies, are designed to improve the prody of each factor. Historically, the major increases in system efficiencies have come from–not labour skilling, but from labour deskilling in the manufacturing sectors of the developed countries. We had Fordist technical efficiencies, then Taylorist, all of which deskilled the traditional artisan into an unskilled wage labourer.

The second twist in this factor, is that in the following phase, labour deskilling is turned back round into reskilling to deal with the new flexible specialisation systems as shown by Piore.

What does this have to do with us in subcontinental agriculture? There is major tenurial change going on here. From sharecropping to wage labour. These changes are being forced by changes in risk, moral hazard, enforcement costs, and overall transaction costs. These transaction costs are leading to important contractual changes which will strongly affect labour productivity. So we have 4 potential sources of increase in TFP. The authors have only looked at one part of one source, HK based on information. I think it is very important that all these 4 sources be taken into account in conceptualising a TFP model. Otherwise we are over attributing sources of growth, if we miss some out. And the whole point of TFP is to avoid the over attribution involved in partial factor productivity.

Empirical Methodology and Interpretation of the Results

Let us look at how change in human capital is estimated. The proxy variable used is research investment–whose form is:

(Cumulated Investment)*(Weighted by relative productivity change)

The variables used for India are literacy, extension expenditure per farm, the stock of research investment, and agricultural patents. Literacy and extension expenditure are valid variables, because they are causally related to productivity. Research investment, and patents are not causally related to productivity unless shown. Therefore the results obtained on account of these research and patent variables are spurious.

The same argument applies to the variables used for Pakistan. Literacy is a valid variable, but the number of research personnel, with or without degrees cannot be related to productivity unless causality is demonstrated in some way.

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