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THE OVERALL RATE OF RETURN TO AGRICULTURAL RESEARCH AND EXTENSION INVESTMENTS IN PAKISTAN

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The purpose of this paper is to identify and establish the contribution of the major sources of overall productivity growth to Pakistan's agriculture. The paper concentrates on the role of research and extension and estimates a rate of return to agricultural research and extension expenditures within Pakistan. The analysis takes the form of estimating (regressing) a total factor productivity index on non-conventional inputs which include research and extension expenditures as arguments. It is estimated that the marginal rate of return to investment in research and extension in Pakistan is 65 per cent.

I. Introduction

Pakistan's agricultural productivity (crops) has increased substantially since 1966-67 as evidenced by the increase in the productivity index presented in Table 1. The purpose of this paper is to identify and establish the contribution of the major sources of overall productivity growth to Pakistan's agriculture. The paper concentrates on the role of research and extension and estimates a rate of return to agricultural research and extension expenditures within Pakistan.

Two main approaches have been used to identify overall sources of productivity growth and establish their contribution. The first is an "inputs saved" approach which, in essence, is the difference between the value of present day technological inputs in producing today's agricultural output

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minus the value of yesterday's (years) technological inputs in producing today's agricultural output. Schultz (1953), in a study of United States agriculture for the period 1920-1950 concluded that, despite the considerable increase in agricultural output over the period, the aggregated value of traditional agricultural inputs remained virtually constant. In a recent study, Brinkman and Prentice (1983) used the inputs saved approach to estimate an internal rate of return to investments in agricultural research and extension. They found that the inputs saved over the period 1956 to 1978 returned an internal rate of return of 65.7 per cent to the Province of Ontario, Canada.

The most popular method of identifying the contribution of agricultural research and extension has been to use a production function. The level of agricultural output is estimated as a function of the level of conventional and non-conventional inputs. The non-conventional inputs such as education, research and extension are included as separate arguments in the production function. A full list of production function type studies are found in Ruttan (1982). Good literature reviews on the topic exist in Davis (1979) and Norton and Davis (1980).

Many production function estimates utilize cross-section or pooled cross section-time series data to avoid multicollinearity problems. Other studies such as Lu et. al. have used a total factor productivity index regressed on the non-conventional inputs in an attempt to alleviate the multicollinearity problem. This is the approach adopted in this study for the following reasons: first, although much of the data exists to estimate a time series production function of the Pakistani agricultural sector severe multicollinearity problems do arise. (For example, the study by Naqvi et. al. (1983) was unable to estimate a convincing agricultural production function for the P.I.D.E. Macro-Economic Model of Pakistan's economy for this reason). Secondly, the data required to estimate a pooled time series cross-section production function model using Census years by Districts although almost complete is deficient.

II. The Productivity Model

Following Lu et. al. (1979), the level of productivity (P_t) in year t is a function of the current weather conditions (W_t), the current education level of farmers (ED_t) and the impact of research (RS_t) and extension (EX_t) in the current year from previous in-country expenditures on research and extension by Pakistan and donor agencies. Since the main objective is to obtain the contribution and rate of return to expenditures on research that the Pakistan research system is involved in, a variable is added

(HYV_t) representing high yielding varieties that are introductions from other countries.[1] The productivity model is specified in equation (1).

$$P_t = A \pi RS_t^{a_1} EX_t^{a_2} HYV_t^{a_3} ED_t^{a_4} e^{a_5 W_t} \quad (1)$$

In the absence of good quality pooled cross section – time series data for the productivity model, the model is estimated using available time series data. For the purpose of estimation, equation (1) is transformed into double logarithmic form as shown in equation (2) which indicates that the level of productivity is a function of the combined research and extension expenditures expressed as a distributed lag (RE), education, HYV introduction and the current weather.

$$\ln P_t = \sum_{i=1}^{n} \alpha_i \ln RE_{t-1} + B_1 \ln ED_t + B_2 \ln HYV_t + B_3 W_t + u_t \quad (2)$$

Multicollinearity problems precluded obtaining separate coefficients for research and extension. Thus research and extension expenditures are combined and are assumed to adopt an inverted "U" shape distribution of the partial production coefficients. This assumption is based on Evenson (1968) and was used by Davis (1979) and Lu et. al. (1979). The assumption is that expenditures on research and extension will have a small impact on productivity increase in the current year of their expenditure but that the impact increases to a peak over time but then decays. The assumption is also made that the distribution of the partial production coefficients can be expressed as a second degree polynominal. The estimation procedure used to calculate the partial production coefficients (α_i) and the construction of the appropriate research and extension variable which is an Almon polynomial lag procedure follows that of Maddala (1977), and David (1979) and is presented in Appendix A.

Table 1 presents the data used in the analysis. The productivity index (PI) is an arithmetic index obtained from Wizarat (1981). The education variable is a literacy index based on rural literacy rates obtained from census figures. The weather variable is in terms of yearly rainfall. The HYV introduction variable is the percentage of HYV wheat and rice hectares sown to imported varieties (i.e., introductions). The research and extension expenditures include both Pakistani and in-country donor agency expenditures.

[1] Variety introductions from other countries are those varieties that have been developed by research systems in other countries and which the Pakistan research system has had nothing to do with in their development. Thus, the HYV introduction variable accounts for the increased productivity of HYV introductions while the RS and EX variables account for in-country expenditures by Pakistan and donor agencies.

TABLE 1

Productivity model variables

Year	Productivity Index	Literacy Index	Rainfall Variable	HYV Intro.	Extension Expenditures	Research Expenditures
	PI	ED	W	HYV	E	R
	(Index 1959-60 = 100)		(m.m.)	(%)	(mil 1959-60 Rs.)	
1948-49	–	–	–	–	10.7	3.7
1949-50	–	–	–	–	4.8	4.1
1950-51	–	–	–	–	5.1	4.0
1951-52	–	–	–	–	4.3	4.1
1952-53	–	–	–	–	4.6	3.6
1953-54	109.3	–	–	–	4.7	3.4
1954-55	109.9	–	–	–	5.4	3.8
1955-56	106.3	–	–	–	5.6	4.3
1956-57	104.3	–	–	–	7.1	7.0
1957-58	102.3	–	–	–	9.3	6.8
1958-59	104.7	–	–	–	12.6	8.0
1959-60	100.0	100.0	563.7	0.0	14.6	8.0
1960-61	89.4	102.1	375.8	0.0	8.1	7.0
1961-62	95.5	104.3	368.2	0.0	11.8	7.3
1962-63	98.6	106.4	352.5	0.0	10.7	8.7
1963-64	101.3	108.7	256.5	0.0	13.8	11.0
1964-65	104.1	110.9	443.2	0.0	16.8	13.6
1965-66	101.0	113.2	273.4	0.0	10.8	8.1
1966-67	106.1	115.6	343.3	0.0	12.1	8.6
1967-68	122.1	117.9	409.1	0.0	11.2	10.2
1968-69	128.3	120.5	276.1	0.1	11.2	10.6
1969-70	133.6	123.0	260.6	1.1	7.2	10.5
1970-71	135.7	125.6	319.2	2.3	8.4	13.5
1971-72	137.0	128.2	264.5	3.6	8.6	8.7
1972-73	136.9	129.8	258.3	4.8	5.5	6.3
1973-74	141.5	131.5	416.6	4.8	6.7	5.4
1974-75	133.9	133.1	262.8	5.6	12.5	5.3
1975-76	139.1	134.8	466.7	8.3	15.6	10.8
1976-77	139.5	136.4	466.2	10.0	15.1	13.7
1977-78	140.2	138.2	317.9	15.3	16.5	15.8
1978-79	144.5	139.9	412.5	20.1	18.5	14.9

Source: The Productivity Index is from Wizarat (1981). The method of calculation and data sources are found in Nagy (1984).

The model in equation (2) was estimated by OLS for the period 1959-60 to 1978-79 using an 8, 10 and 12 year lag of the research and extension variable. Table 2 presents the results using a 10 year second degree polynomial research and extension lag variable with end points constrained to be zero.[2] The 8 and 12 year lag models were statistically inferior to the 10 year lag model. All models that included the literacy index variable were also statistically inferior.[3] A dummy variable (D65) is added to capture the effect of the Pakistan-India war. The war affected both the level of the research and extension expenditure (Table 1): Agricultural value added decreased in this period [Wizarat, (1982)], which in turn decreased the 1965-66 productivity index. Dummy variables, to capture the Pakistan-Bangladesh conflict and the 1973-74 Tarbela dam problem were tried without success. In all models, the weather variable presented a problem. The problem in part may arise from the unexpected high correlation between the weather and research and extension variables.

Secondly, rainfall may not be a good measure of weather effects because it is averaged over all of Pakistan on a yearly basis and is not combined with a temperature variable that accounts for stress periods in the plant. Thirdly, about 70 per cent of Pakistan's cropped land is irrigated and 85-90 per cent of all wheat production and all rice production are grown on irrigated land (Agricultural Statistics of Pakistan). Thus the variation in overall total yields due to rainfall and overall weather effects are dampened.[4]

III. Estimation of the Overall Rate of Return

A double-log function was used to estimate the parameters of equation (2), therefore the partial production coefficients are elasticities and their

[2] Constraining the endpoints to zero suggests that the knowledge and benefits gained from research and extension activities depreciate to zero and may be an overly strict assumption. A model was estimated without endpoint constraints and the resulting F statistic did not reject the null hypothesis that the endpoint constraints are zero. The coefficient on the research and extension variable of the non-restricted model are slightly larger than those presented in Table 2 for the restricted model.

[3] The effect on increased productivity may indeed be small and not significantly different than zero with respect to rural education. The overall literacy rate in Pakistan only increased from 21.7 per cent in 1971-72 to 24 per cent in 1979-80, (Pakistan Economic Survey). For the same period the literacy rate of rural males ages 20-24 increased from 31.1 per cent to only 34.8 per cent. Not only is this a small increase, but the increase is biased upward for our purposes because the rural category includes medium size towns whose occupants would receive more education than the more remote villages where the majority of farmers live.

[4] Other models were estimated using various forms of the variables already outlined including a Solow productivity Index [Wizarat, (1983)] without substantial difference in the results.

TABLE 2

Distributed lag model parameter estimates

Explanatory Variable	Distributed Lag Models		
	I	II	III
Constant	0.734 (0.83)	0.593 (0.70)	1.224 (1.71)***
HYV	0.036 (8.59)*	0.035 (8.25)*	0.035 (8.29)*
W	0.0003 (1.50)***	0.0002 (1.33)*	—
D65	—	−0.094 (−1.63)***	0.105 (−1.80)**
Distributed Lag Weights.			
0	0.019	0.019	0.017
1	0.034	0.035	0.030
2	0.045	0.046	0.040
3	0.052	0.054	0.047
4	0.056	0.058	0.050
5	0.056	0.058	0.050
6	0.052	0.054	0.047
7	0.045	0.046	0.040
8	0.034	0.035	0.030
9	0.019	0.019	0.017
Sum of Weights	0.412 (4.76)*	0.424 (5.16)*	0.368 (4.32)*
ADJUSTED R^2	0.891	0.901	0.897
D.W.	1.07	1.49	1.44
D.O.F.	16	15	16

T-Statistics are within parentheses. D.W. is the Durbin-Watson 'd' statistic. *Significant at the 1 per cent level. **Significant at the 5 per cent level. *** Significant at the 10 per cent level.

sum the total production elasticity. The marginal product of the research and extension variable (RE) for each year in the lag is given as:

$$MP_{t-i} = \alpha_i \frac{\overline{P}}{\overline{RE}}; \; i = 0 \text{ to } q \qquad (3)$$

where $\overline{P}$ and $\overline{RE}$ are the average of the productivity index P and the research and extension variable RE. It is, however, the value of the marginal product (VMP) that is required thus each annual marginal product in the 10 year lag must be multiplied by the value of one unit of productivity index P. This is done as follows [Lu et. al. (1979), and Cline, (1975)] :

$$VMP_{t-i} = \alpha_i \frac{\overline{P}}{\overline{RE}} \cdot \frac{\Delta Y_t}{\Delta P_t} \; ; i = o \text{ to } q \tag{4}$$

where ΔY_t is the change in the value of output net of the change in the value of inputs and ΔP_t is change in the productivity index between years.[5]

The calculation of the VMP summing equation (4) over the 10 year lag indicates a VMP of Rs4.93. Thus an investment of Re1.00 in agricultural research and extension will yield a return of Rs4.93 over a 10 year period. Given that the returns are distributed over time, the present value of the discounted VMP's at a rate of 10 and 15 per cent yields Rs3.24 and Rs2.75 respectively from a Re1.00 investment.[6]

In keeping with the conventions of other studies of this type, a marginal internal rate of return (MIRR) is calculated using the following formula.

$$1 - \sum_{i=0}^{k} \frac{VMP_{t+i}}{(1+r)^i} = 0 \tag{5}$$

MIRR is that discount rate r which equates the discounted future returns with the initial investment. Performing the calculations, MIRR is 64.5 per cent.

The rates of return estimated above are the returns to in-country investment in the Pakistani research and extension system from federal and provincial governments, PARC and donor agencies. It is not possible to examine the rate of return to individual contributors separately. Also, the rates of return do not include expenditures for research done at international centers. If Pakistan had to support international centers such as CIMMYT and IRRI in proportion to the benefits they receive (i.e., genetic material), the rate of return would be much lower. Unfortunately, the type of infor-

[5] To be more precise, the basic equation used to calculate an arithmetic productivity index P is given by: $P_1 = [V_1/(r_0K_1 + w_0L_1]/[V_0/(r_0K_0 + w_0L_0)]$ where; V = the value of output, K = the physical quantity of capital, L = the physical quantity of labor and $r = VMP_K$, $w = VMP_L$ representing the price of capital and labor respectively [see, Lu et. al. (1979, pp. 6-7) and Cline, (1975, pp. 91-94) for the derivation of the arithmetic productivity index to this point]. Thus $\Delta P = P_2 - P_1$ and $\Delta Y = V_2 - V_1 - [(r_0K_2 + w_0L_2) - (r_0K_1 + w_0L_1)]$.

[6] $PV = \sum_{i=0}^{k} [VMP_{t+1}/(1+r)^i]$.

mation needed to calculate such a rate of return is not available. In this analysis, support from international agencies is looked upon as a free good. Thus the rate of return figures can be looked upon by the individual contributors to the Pakistan agriculture research and extension system as an overall average (marginal) return that might be expected from a broad-based research and extension agenda.

The rate of return figures estimated above are large but within the bounds of what might be expected based on returns from similar analyses of other countries. For example, Barletta's study on Mexico (45-93 per cent) and Kahlan, Bal, Saxena and Jha's study on India (63 per cent) indicate similar results [Ruttan, (1982), p. 243)].

Other researchers [Peterson, (1967); Evenson, (1968); Lu et. al. (1979)] have adjusted their results to take account of private industry R&E and R&E from other sources. Although small pockets of private research exist such of Rafhan Maize Company's research on hybrid maize, their overall impact is very small [Pray, (1982)]. The HYV introduction variable was used to account for other sources of R&E to which the Pakistan research system had not contributed. Thus, it is claimed that the VMP's from the estimated models come from R&E investments by the principal contributors to R&E. However, if one were to suppose that only two-thirds of the VMP could be claimed by the principal contributors to R&E the rates of return would still be very high at a rate of 39 per cent.

IV. Summary and Conclusions

This paper empirically estimated the overall rate of return to all agricultural research and extension expenditure in Pakistan. The analysis took the form of estimating an equation portraying a Pakistan total factor agricultural productivity index as a function of weather, education, research and extension expenditures plus a variable to account for HYV introductions. Due to multicollinearity problems, research and extension expenditures were combined into a single variable. A marginal internal rate of return of 65 per cent was estimated and, although high, it compares with the rates of return obtained from similar studies in other countries.

Economic principles dictate that investment in a particular enterprise should continue until the rate of return is equal to the returns to investments in other enterprises. Unfortunately, the full range of return figures for all investments in Pakistan are not available. However, given the magnitude of the rate of return to agricultural research and extension in Pakistan, the Pakistan government and the donor agencies should look upon agricultural research as a favourable place to invest.

The favorable rate of return to investments in the Pakistani agricultural research and extension system suggest that Pakistan and donor agencies have, over the years, received a good return. However, the high rates of return cannot be interpreted to mean that Pakistan's agricultural research and extension system is performing to full capacity in increasing the growth in agricultural output and productivity. Problems of low funding and low levels of quality scientists and staff within the research and extension system have constrained the benefits from research and extension, [Nagy, (1984)]. Also, the research and extension system cannot be looked at in isolation of the environment within which it operates. That is low product prices, the low level of education, and the unavailability of high payoff inputs such as high quality HYV's, fertilizers, and improved practices have also constrained Pakistan's output and productivity growth, [Nagy, (1984)]. Thus, along with an increased emphasis on agricultural research and extension, an increased emphasis must also be made to deliver a total package of inputs including favorable product prices to the farmers.

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Appendix A.

The estimation procedure used to calculate the partial production coefficients (α_i) and the construction of the appropriate research and extension variable which is an Almon polynominal lag procedure follows that of Maddala [(1977), pp. 356-359] and Davis [(1979), pp 69-71] and is presented as follows:

A second degree polynomial is given in equation (A.1) as

$$\alpha_i = b_o + b_{1i} + b_{2i}^2 \qquad (A.1)$$

where: i = 0 . . . k and i = t = 0 in the current year (thus k = 1 – the number of years in the lag),

By constraining the endpoints to be zero, that is $\alpha_{-1} = 0$ and $\alpha_{k+1} = 0$ in equation (A.1), the following relationship is obtained.

$$b_0 + b_1 (-1) + b_2 (-1)^2 = 0 \qquad (A.2)$$

$$b_0 + b_1 (k+1) + b_2 (k+1)^2 = 0 \qquad (A.3)$$

where equations (A.2) and (A.3) simplify to:

$$b_0 = -b_2 (k+1) \qquad (A.4)$$

$$b_1 = -b_2 k \qquad (A.5)$$

By substituting (A.4) and (A.5) into (A.1) and then substituting the result into a productivity model [i.e., an equation similar to (2) in the text], the following is obtained;

$$\ln P = b_2 Z_t + B_1 \ln HYV_t + B_2 W_t + u_t \qquad (A.6)$$

where:

$$Z_t = \sum_{i=0}^{k} (i^2 - k_i - k - 1) \ln RE_{t-1} \qquad (A.7)$$

The model in equation (A.6) is then estimated to obtain b_2 which is then substituted into equations (A.4) and (A.5) to obtain b_0 and b_1. Equation (A.1) is then used to obtain the partial production coefficients (α_i), the sum of which represents the total production elasticity.

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