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Total Factor Productivity Growth and Agricultural Research and Extension: An Analysis of Pakistan's Agriculture, 1960–1996

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INTRODUCTION

Pakistan's agriculture has grown rapidly since the 1960s, with an average annual growth of about 4 percent over the four decades till the end of the century. Agricultural growth at this rate was sustained by the technological progress embodied in the high-yielding varieties of grains and cotton, with supporting public investment in irrigation, agricultural research and extension (R&E), and physical infrastructure. This rate of agricultural growth has significantly contributed to the overall economic growth of about 6 percent per year during this period. Sustaining this performance presents a considerable challenge for the public policy framework for agriculture, not the least for the agricultural research and extension system in Pakistan.

The central role of technological change in increasing agricultural productivity is well established in the wake of the Green Revolution experience across much of Asia. In the context of Pakistan, it has been estimated that almost 58 percent of the total output growth from 1960 to 1996 was due to technological change [Ali (2000)]. While improvements in the physical and market infrastructure, farmer education, price policies, and weather, all have their place in enhancing agricultural production, R&E investments has been regarded by far the most important contributor to agricultural productivity growth [Evenson and Rosegrant (1993); Byerlee (1994)].

Studies evaluating agricultural research have usually found high rates of return to investment—much higher than alternative investment opportunities—

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indicating non-optimal allocation of societal resources. Given the tight budget that most national governments face, the only way to enhance research budgets or to keep them from falling is to make a cogent case based on the potentially high rates of return that can be obtained from agricultural research investment. This study is an attempt to develop such a case based on estimates of the rate of return to agricultural research and extension in the agricultural sector of Pakistan.

AGRICULTURAL RESEARCH AND EXTENSION IN PAKISTAN

The agricultural research system in Pakistan includes research organisations at both the federal and provincial levels. Extension is largely carried out by the provincial agricultural departments. The agricultural research and extension system in Pakistan, despite its constraints, has performed reasonably well over the years. During the early days of the Green Revolution, adaptive research experiments by the research institutes and the dissemination of the results by the extension agency played an instrumental role in the rapid spread of High Yielding Varieties (HYVs) of wheat and rice. During the 1980s, the rapid growth in cotton productivity was a result of a major breakthrough by the national research system in developing a high yielding variety for cotton. This notwithstanding, the research system's performance over the period lagged behind that of other countries with comparable agricultural conditions (Table A.1). In 1996, except for cotton, Pakistan's yield/hectare for wheat, rice and sugarcane, the major crops, was sizably lower than India—a neighbouring country with nearly similar soil and weather conditions. Cotton output/hectare in Pakistan is only two-thirds of the yield level in Egypt and Mexico. There is a still a substantial shortfall within the country between the best performance yields on the experimental plots and what the farmers achieve on their farms, the so-called "yield gap" [Byerlee (1994)] requiring bold initiatives for improving the efficiency and effectiveness of the agricultural research and extension system.

REVIEW OF THE LITERATURE

The relationship between agricultural research expenditure and agricultural output/productivity is usually explored in a production function setting with specifications varying according to the nature of the data and objectives of the study [Knutson and Tweeten (1979); Norton and Davis (1981); Evenson and Pray (1991)] As the impact of research and extension on output/productivity spans over many time periods, proper modeling of the lag relationship assumes considerable importance in the overall modeling strategy. To circumvent the econometric problems relating to degrees of freedom and multicollinearity, researchers have used a variety of different deterministic lag formulations ranging from simple averages over time periods to more sophisticated versions such as geometric, inverted V, trapezoidal, and polynomial lags.

Davis (1980), estimated an aggregate output Cobb-Douglas production function model for U.S. agriculture with a range of alternative lag structures and found that the conventional input coefficients as well as the research production coefficient were, by and large, the same across all specifications.[1] Use of the simplistic lag formulations in this context saves on the data collection effort. Pardey and Craig (1989) in their study find that while summary statistics of the lag relationship such as the mean and variance are generally not very sensitive to the choice of the lag structure, the implied rate of return to agricultural research is, however, quite sensitive to partial research production coefficients that are estimated with models with inappropriate lag structures. To fully account for the effect of research on output/productivity, the study indicated the need for long lags of at least thirty years.

Fernandez-Cornejo and Shumway (1997) have examined the agricultural research productivity relationship for Mexican agriculture for the period 1940-90. First, a Tornqvist-Theil (T-T) Total Factor Productivity (TFP) index is calculated. Then, in an application of two-stage TFP decomposition procedure, a regression model explaining TFP in terms of agricultural research spending (public research and agricultural extension) and a proxy for international transfer of technology are proposed.[2] Applying cointegration technique, the authors were able to determine a unique long-run relationship between TFP, agricultural research investment, and U.S. agricultural productivity—used as a proxy for international transfer of technology in Mexican agriculture. Using the productivity elasticity of research from the estimated relationship, the average annual rate of return to research investment is estimated at 64 percent. Makki, Thraen, and Tweeten (1999), explain productivity growth in U.S. agriculture sector in terms of time-series data on public and private research investments, farmers' education, terms of trade, government commodity programmes, and weather. A significant cointegrating relationship is found between research investment and agricultural productivity. Based on the estimated coefficients on the lags of public and private research variables, the authors estimate the internal rate of return of 27 percent for the public R&E and 6 percent for private R&D.

In the context of Pakistan, Khan and Akbari (1986) estimated a relationship between agricultural output and agricultural research and extension in a production function setting with a 10-year lag structure and found the rate of return to agricultural research to be 32 percent. Nagy (1991) estimated a productivity decomposition model for the period 1959-60 to 1978-79, in which TFP is functionally related to current weather conditions, current education level of farmers

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[1] Six different formulations for lag structures ranging from the simplest requiring use of only the current year's expenditure level to the more complicated constrained polynomial lag were used.

[2] A proxy for farmers' education was included in a preliminary specification but found to be collinear with other variables and statistically insignificant. Weather proxies similarly were found to be statistically insignificant as was to be expected given that Mexico straddles many climatological zones.

and the impact of research and extension. In an ordinary least squares estimation, eight, ten and twelve year lags for the research expenditure and extension variable were tried and Nagy found the ten-year lag to be statistically superior to the other two lag specifications. Utilising the estimated coefficients of research and extension, the marginal internal rate of return to agricultural research and extension in Pakistan was calculated to be 64.5 percent. Rosegrant and Evenson (1993), in their study of TFP for Pakistan's crop sector, found research variables, share of modern varieties, literacy and overall share of irrigation to have the greatest impact on productivity growth. Their estimate of the marginal rate of return to crop-specific research is 58 percent, general research 39 percent, and that specific to HYVs 51 percent.

Methodological Framework

The relationship between productivity growth and R&E investment is commonly explored with the following Cobb-Douglas specification [Lu, *et al.* (1978); Norton and Davis (1981); Thirtle and Bottmley (1989); Nagy (1991)].

$$P = AW^{\gamma}E^{\theta}\prod_{i=0}^{n} R_{t-i}^{\alpha_{t-i}} .e^{\nu} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \qquad (1)$$

where P is the productivity index of agricultural output; W is the weather index; E is a measure of the schooling level of farmers; R_{t-i} is expenditure on R&E; α_{t-i} are the partial productivity coefficients of R&E in the *i*th year; and γ and θ are the productivity coefficients for the other inputs. It is also quite commonplace in the literature to make ad hoc additions of explanatory variables to this specification to control for infrastructural and other policy effects on productivity [Evenson and Pray (1991); Evenson, *et al.* (1999)].

In the context of agricultural research, the lag structure—its shape, order and length—is usually decided on the basis of prior knowledge about various time phases in the generation of agricultural research and its application. In general, the research-adoption process in agriculture consists of three time phases: (1) research lag between the initiation of research and generation of pretechnology knowledge; (2) development lag, when results from pretechnology research are incorporated into useful technology; and (3) adoption lag between the release of agricultural technology and its optimal adoption by farm producers. [Alston, *et al.* (1995)]. The extent of the lag in a particular situation would depend on whether the activity was initiated from scratch or there was scope for building on the work/results obtained elsewhere. In most developing countries, the agricultural research activity typically begins with the importation of basic technology developed elsewhere, which is then adapted to local conditions on the basis of field trials in various agro-climatic zones. In this case, the lags are shorter than those associated with research of a more fundamental nature. In some contexts—U.S. agriculture, for example—lags extending back 30 years are considered appropriate. In Pakistan, the average lag between the availability of technology and its adoption, against the Green Revolution background, is generally considered to be about 8-12 years. Khan and Akbari (1986) and Nagy (1991) have used lag structures of ten years and eight years, respectively.

It is customary to postulate that the impact of agricultural research is small to begin with, but gradually builds overtime to a peak level and, then, decays till it becomes negligible [Thirtle and Bottomley (1989); Nagy (1991)]. While various lag schemes have been tried to model these effects, the second-degree polynomial lag scheme—the Almon lag—is used frequently. Its advantage lies not only in its ability to mimic the postulated inverted 'U' shape diffusion process of agricultural research but also in its convenient estimation technique that avoids problems of collinearity and degrees of freedom inherent in an unrestricted lag estimation.[3]

DATA

The total factor productivity index for Pakistan's agriculture sector has been calculated by Ali (2000) using the T-T TFP methodology. Agricultural research data is not reported on a regular basis in the official publications. It had to be collected from various agencies of the government. The agricultural research data pertains to the four provinces—Punjab, NWFP, Sindh and Balochistan—and the federal government (West Pakistan) for the period before the present provincial set-up came into being. While the provincial expenditures include the development and non-development expenditures on the provincial research institutes, data for the Pakistan Agricultural Research Council (PARC) and the Pakistan Central Cotton Committee (PCCC), autonomous bodies under the federal government, was obtained separately. The provincial and federal data were added together to generate a total annual research expenditures series for the period 1960-96. As these figures were available in current terms, they had to be converted into real terms using the GDP deflator with base 1980-81. The use of GDP deflator has been necessitated by the fact that a more closely relevant deflator is not available in Pakistan.

The extension activity is almost entirely carried out the agriculture departments of the provincial governments. The salaries and other recurring costs of extension services are met from the provincial non-development (revenue) budget. The total annual extension expenditure has been estimated by deducting the agricultural research expenditure (non-development and development) of all four provinces from the total expenditure (non-development and development) of provinces on agriculture. While total provincial expenditure (non-development and

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[3] Endpoint restrictions are also typically imposed to obviate the possibility of implausible negative coefficients at the beginning and the end of the lag distribution as can often happen with the recovery of lagged parameters from the estimation of only three parameters of a quadratic polynomial function [Alston, *et al.* (1995), p. 182].

development) on agriculture is reported in official documents, agricultural research expenditure (non-development and development) for the provinces were not readily available. This data had to be collected informally through the relevant agencies. The annual extension expenditure data had to be deflated with GDP deflator to convert it into real terms.

PRODUCTIVITY-RESEARCH RELATIONSHIP: MODEL AND ESTIMATION

The relationship between productivity and R&E, in the context of Pakistan, can be specified as:

$$TFP = A..\prod_{i=0}^{n} RES_{t-i}^{\alpha_{t-i}}.e^{T+D1+\varepsilon} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (2)$$

Where TFP = total factor productivity index using the T-T procedure;

RES = real agricultural R&E expenditures(R&E);

T = time trend;

$D1$ = 0-1 dummy variable to capture the influence of weather, floods etc. during 1974-75, 1983-84, and 1992-93.

ε = error term.

The model is estimated in log-log form with annual time-series data for the sample period (1960–96). The coefficients of the R&E variable are assumed to lie on a quadratic Almon polynomial lag. The justification for using the R&E variable is obvious in the context where the major productivity gains are attributed to new agricultural technologies including the introduction of the new hybrid seeds technology. A weather variable is usually included in a specification of this type, but in the present case no suitable weather time-series was available.[4] Therefore, weather dummies are being used to capture the influence of weather for three of the most affected years.[5] A time trend has been added to capture the influences on TFP

[4] Nagy (1991) in his estimation of the productivity-research relationship for the crop sector in Pakistan for the years 1959-60 to 1978-79 found that weather turned out to be insignificant in all his models. Based on this outcome, he concludes, "the problem, in part, may arise from the unexpectedly high correlation between the weather and RE variables. Second, 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 account for stress periods in the plants. Third, about 70 percent of Pakistan's cropped land is irrigated, and 85-90 percent of all wheat and all rice are grown in irrigated land. Thus the variation in overall total yields attributable to rainfall and overall weather effects is dampened." (p. 109) Khan and Siddiqui (1982) have also argued that "rainfall alone cannot be a proper measure of the influence of weather on crop growth and information on other equally important components of weather is usually not available or difficult to incorporate." (p. 150).

[5] The dummy variable takes the value of 1 for the years 1975, 1984, and 1993 to capture the extraordinary weather/climatic events during these years.

systematically changing with time. An education/schooling variable has *not* been included because census data is only available at ten year intervals and the within censuses interpolated data may not be adequate for the purpose. Nagy (1991), who constructed a literacy index from the rural literacy data from population censuses, has found that “all models that included the literacy index variable were also statistically inferior” (p.108).

The results of estimations with lagged R&E variable are presented in Table 1. First the specification was estimated with twelve lags in the light of the previously

Table 1

Distributed Lag Parameter Estimates

Dependent Variable: log TFP			
Constant	–1.59	–3.91	–3.72
	(–0.76)	–1.37	(–1.27)
Trend	–0.007	–0.015	–0.014
	(–0.72)	(–1.10)	(–1.00)
Dummy Variable	0.027	0.031	
	(1.13)	(1.41)	
Estimated Lag Coefficients	Twelve Lags	Sixteen Lags (with Weather Dummy)	Sixteen Lags (without Weather Dummy)
0	0.009	0.008	0.007
1	0.017	0.015	0.014
2	0.024	0.021	0.021
3	0.029	0.026	0.026
4	0.033	0.031	0.030
5	0.035	0.034	0.033
6	0.036	0.036	0.035
7	0.035	0.038	0.037
8	0.033	0.038	0.037
9	0.029	0.038	0.037
10	0.024	0.036	0.035
11	0.017	0.034	0.033
12	0.009	0.031	0.030
13		0.026	0.026
14		0.021	0.021
15		0.015	0.014
16		0.008	0.007
AIC	0.0018	0.0010	0.0010
Schwartz	0.0021	0.0012	0.0012
Sum of Lags	0.335	0.463	0.452
T-ratio	(2.94)	(2.91)	(2.78)
R-Sq Adj	0.94	0.96	0.96
D.W.	0.83	1.50	1.74
P-value	0.603	0.347	0.867
DOF	(12,9)	(16,1)	(16,2)

Note: Numbers in parenthesis are *t*-values.

observed lag length of 8-12 years. However, the specification with sixteen lags performs better than that with twelve lags. It explains 96 percent of the variation in agricultural productivity and also has lower values for both the AIC and Schwartz criteria. The estimated value for the *F*-test on restrictions—resulting from constraining the coefficients to lie on a second-degree polynomial as well as restrictions on the endpoints of the lag distributions—are 0.862, 4.761 and 0.434 for twelve lags, sixteen lags (with weather dummy) and sixteen lags (without weather dummy) respectively. These values do not reject the null hypothesis that the restrictions are valid. The lag coefficients are significant, symmetric U-shaped and rise to a peak value of 0.037 in eight periods. Total lag effect (sum of lags) is significantly different from zero and adds up to 0.452, which in the context of this log-log specification can be interpreted as a 1 percent increase in the R&E variable leading to an increase of 0.45 percent in the TFP index. Both the time trend and the dummy variable for years of calamitous weather are wrongly signed but insignificant. The specifications with twelve lags and sixteen lags with the weather dummy included have low D.W values compared to the specification with sixteen lags but without the weather dummy. The specification without the dummy variable has been chosen for the purposes of estimation of the marginal rate of return to R&E.

Marginal Internal Rate of Return to Research and Extension

A standard methodology for estimation of the marginal internal rate of return to R&E expenditures is widely used in the literature [Knutson and Tweeten (1979); Thirtle and Bottomley (1989); Nagy (1991); Fernandez-Cornejo and Shumway (1997) and Evenson, Pray and Rosegrant (1999)].

The estimation of the MIRR involves the relationship in Equation (2) being estimated in double log form, with each lag coefficient on the R&E variable representing the productivity elasticity of R&E for that year. This can be written as:

$$\alpha_i = \frac{\partial \log TFP_t}{\partial \log RES_{t-i}} = \frac{\partial TFP_t}{\partial RES_{t-i}} . \frac{RES_{t-i}}{TFP_t} \quad \ldots \quad \ldots \quad \ldots \qquad (3)$$

Rearranging the above elasticity expression, the marginal physical productivity of research can be expressed as:

$$\frac{\partial TFP_t}{\partial RES_{t-i}} = \alpha_i .(\frac{TFP_t}{RES_{t-i}}) \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \qquad (4)$$

Replacing $\frac{TFP_t}{RES_{t-i}}$ by the means of these variables for the period under consideration and using discrete approximations leads to:

$$\frac{\Delta TFP_t}{\Delta RES_{t-i}} = \alpha_i \left(\frac{\overline{TFP}}{\overline{RES}_{t-i}}\right) \qquad \ldots \qquad \ldots \qquad \ldots \qquad \ldots \qquad \ldots \qquad (5)$$

The change in productivity can be converted into a change in the value of output if both sides of Equation (14) are multiplied by the average increase in the net value (net of inputs) of output (*Y*) caused by a one index point increase in productivity:[6]

$$\frac{\Delta TFP_t}{\Delta RES_{t-i}} . \frac{\Delta Y_t}{\Delta TFP_t} dTFP_t = \alpha_i \left(\frac{\overline{TFP}}{\overline{RES}_{t-i}}\right) . \frac{\Delta Y_t}{\Delta TFP_t} dTFP_t \qquad \ldots \qquad \ldots \qquad (6)$$

From this, the value marginal product of research in period (*t–i*) can be written as:

$$VMP_{t-i} = \frac{\Delta Y_t}{\Delta RES_{t-i}} = \alpha_i \left(\frac{\overline{TFP}}{\overline{RES}_{t-i}}\right) . \frac{\Delta Y_t}{\Delta TFP_t} \qquad \ldots \qquad \ldots \qquad \ldots \qquad (7)$$

With the value of output $\left(\frac{\Delta Y_t}{\Delta TFP_t}\right)$ and $\left(\frac{\overline{TFP}}{\overline{RES}_{t-i}}\right)$ calculated as averages, α_i varies over the lag period providing a series of marginal value products resulting from a unit change in R&E expenditures. The marginal internal rate of return (MIRR) can be obtained from these annual flows of value benefits from a unit change in R&E expenditure with the following standard formula:

$$\sum_i^n \left[\frac{VMP_{t-i}}{(1+r)^i}\right] - 1 = 0 \text{ where } n \text{ is the length of the lag.} \qquad \ldots \qquad \ldots \qquad (8)$$

The marginal internal rate of return to R&E has been estimated with productivity elasticities from the specification with 16 lags. The estimated rate of return at 88 percent, is a high return both absolutely and in relation to what can be earned on alternative investments. This high rate of return is a strong indicator of underinvestment in R&E for Pakistan's agriculture. High rates of return to agricultural research have been found in many studies (Table 2).[7] Even where methodologies have differed, the rates of return have been generally much higher than the return on alternative investments.

[6] As the outputs used in the estimation of the T-T output index only covered about 70 percent of the total agricultural output, pre-aggregated gross value of output (at 1980-81 prices) data reported in Kemal and Ahmad (1992) were used for estimation of net value of output.

[7] The high documented returns to agricultural research in Pakistan have been mainly generated by varietal improvement research programmes for the major crops, some of which have been conducted in co-operation with the international research centres (such as IRRI for rice and CIMMYT for wheat).

Table 2

Returns to Agricultural Research in Pakistan and Other Countries

	Country/ Period of Study	Methodology	Type of Research/ Commodity	MIRR (%)
Azam, *et al.* (1991)	Pakistan 1956-85	TFP Decomposition	All Research	58
Evenson and Bloom (1991)	Pakistan 1955-89	TFP Decomposition	All Research	65
Nagy (1984,1991)	Pakistan 1960-79	TFP Decomposition	All Research	64.5
Azam, *et al.* (1991)	Pakistan 1956-85	TFP Decomposition	Wheat Cotton	76 102
Iqbal (1991)	Pakistan 1971-88		Cotton	
			Punjab	90
			Sindh	50
Khan and Akbari (1986)	Pakistan 1955-81	Aggregate Production Function	All Research and Extension	36
Kahlon, *et al.* (1977)	India 1960-73	Aggregate Production Function	All Research	63
Evenson and Mckinsey (1991)	India 1958-83	TFP Decomposition	Public Research Extension	218 176
Salmon (1991)	Indonesia 1965-77	TFP Decomposition	Rice Research	151
Evenson, Pray and Rosegrant (1999)	India 1956-87	TFP Decomposition	Public Research Public Extension	58 45
Thirtle, *et al.* (1993)	Zimbabwe 1970-90	TFP Decomposition	All Research and Extension (Commercial Farms)	40-60
Thirtle and Bottomley (1989)	U.K 1967-87	TFP Decomposition	All Research and Extension	100
Thirtle, *et al.* (1995)	European Agriculture 1973-89	TFP Decomposition	All Research (Public)	
	Greece			564
	Italy			85
	Netherlands			102
Fernandez-Cornejo and Schumway (1997)	Mexico 1940-90	TFP Decomposition	All Research and Extension	64

Source: National Master Agricultural Research Plan (1996-2005), PARC, MINFA, Islamabad; Evenson, Pray and Rosegrant (1999) Table 32.

CONCLUSION AND POLICY IMPLICATIONS

The impact of R&E investment on TFP growth in Pakistan's agriculture has been analysed within a distributed lag framework. The estimation of the productivity-R&E relationship provided evidence of a strong relationship, explaining 96 percent of the variation in the TFP index. The marginal internal rate of return on R&E investment is estimated at 88 percent. This rate of return may look unusually high but it is well within the range of returns estimated in the context of developing and developed countries. The high rate of return is an indicator not only of underinvestment in R&E but also of the constraints on the research and extension system that prevent optimal performance that should drive down this high rate of return to the level on alternative investments.

The existing research system while it has substantial achievements to its credit in the field of plant breeding research, as evidenced by the varieties released for wheat, rice and cotton and the high pay-off genetic gains embodied in them, the crop and resource management research (CRMR) has not been at par. With an effective CRMR programme, we would not have seen the prevalence of farm level inefficiencies in input use, mainly fertiliser and water, that we see today. Strengthening CRMR for meeting the productivity and sustainability challenges of the future requires decentralisation and rationalisation of the existing system. The goal should be a revamped system with a multidisciplinary and site specific approach based on active participation of the farmer [Byerlee (1994)]. While this poses a critical medium-term institutional reform challenge, what is needed above all, for an effective research system in the short term is an enhancement in its funding levels. According to a study by Nagy and Quddus (1998), an optimally funded Pakistan agricultural research system needs to be funded at five to six times the present funding levels. "A research system funded at this level would approach international agricultural research standards, one that could deliver significant productivity and production increases. This would bring Pakistan's funding of agricultural research closer to the funding level of 1.5 percent of Agricultural Gross Domestic Product (AGDP) recommended by the National Commission of Agriculture[8]" [Nagy and Quddus (1998), p.181].

In the post Green Revolution period, the farming environment has grown more complex not only because of the multiple cropping systems made possible by the new technology but also because of emerging sustainability concerns of intensified use of inputs. In areas with diminishing returns to further input intensification, farmers need to switch from intensified input use to new input conserving strategies to sustain profitability and productivity growth. It is clear that a one-way, standardised message or 'recipe' approach to extension is no longer

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[8] Report of the National Commission on Agriculture (1988). Ministry of Food and Agriculture, Government of Pakistan, Islamabad.

workable in this context. The knowledge and improved management skills for adapting to the changing agricultural environment can only be imparted through an upgraded extension agency that has an enhanced capacity for problem solving in diverse locales. This requires not only upgrading the skills of the existing extension agents through enhanced field oriented training but, more importantly, improving the linkages between research, extension and the farmers. For this to happen both research and extension workers would have to increase their interactions with the farmers and incorporate farmer concerns much more explicitly into their work plans than before. One way of doing this would be to decentralise the adaptive research organisation to the local level.[9]

While improvements in research-extension-farmer linkages and greater accountability of these public agencies to the farmers would enhance their effectiveness, the likely payoffs would remain limited unless accompanied by substantial investments in basic education of the farmers. It is widely recognised that literate farmers—with formal schooling—are better adapters to changes in the technological and economic environment than the less literate. The required investments for rapid spread of basic education in the rural areas should figure prominently on the budgetary priorities of the government.

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[9] The farmers' demand for new technologies, crop, livestock and resource management information would be met by these localised adaptive research establishments, who would be acting as the meeting point for suppliers and demanders. With the local adaptive research set-ups serving as avenues for a "two-way dissemination of information between research establishment (suppliers) and farmers (demanders)—a large part of the extension service can be done effectively through these entities in collaboration with the private sector companies and farmers (village) organisations" [Khan (1998), p. 333].

Annexure

Table A.1

Yield per Hectare Performance for Main Crops in Main Producing Countries, 1961-65, 1980, 1996

	Wheat (Kg/Hectare)	Rice (Kg/Hectare)	Cotton (Kg/Hectare)	Sugar Cane (Kg/Hectare)
World				
1961-65	1209	2040	957	49394
1980	1877	2770	1277	54328
1996	2536	3730	1581	61304
Pakistan				
1961-65	833	1417	783	34247
1980	1563	2418	1017	38271
1996	2018	2451	1463	46963
India				
1961-65	835	1480	388	44807
1980	1436	2010	488	49358
1996	2510	2811	922	65892
Mexico				
1961-65	2085	2290	1717	61530
1980	3771	3456	2633	66869
1996	3894		2468	76573
Brazil				
1961-65	707	1607	627	43332
1980	872	1570	865	56069
1996	1800	2558	1187	67227
China				
1961-65	882	2780	903	54555
1980	1878	4200	1651	49019
1996	3759	6062	2302	53197
U.S.A				
1961-65	1700	4374	1488	88001
1980	2249	4946	1211	82497
1996	2442	6860	2043	74010
Egypt				
1961-65	2621	5307	1764	90061
1980	3225	5755	2678	84060
1996	5638	8291	2326	109533

Source: FAO Production Yearbooks (Various Years).

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Comments

Dr Shujat Ali has analysed the impact of Research and Extension (R&E) investment on total factor productivity (TFP) growth in Pakistan. He also estimates the marginal internal rate of returns to investment in agricultural R&E. The study provides evidence on high pay-off from investment in research and extension. The author has used country level data for estimating the relationship between TFP and R&E. The author has a sound background in the methodology used. In the overall, this paper is quite illuminating and interesting however, I have few comments that would help improving the quality and usefulness of the study if incorporated.

The author included few variables (trend variable and weather dummy) in addition to R&E and a reasonable number of it lags in the estimated model. This makes the model too simple. The author should have included in the model other important independent variables like infrastructure. Similarly, there is a need to update the estimates by including data beyond 1960 to 1996 period.

The author, soon after specifying the model to be estimated, stated that justification of R&E variable is obvious in the context where the major gains are attributed to the introduction of the new hybrid seeds technology. The study used the R&E variable which is in aggregate form and gains from it should be attributed to all the technologies resulting from such an investment. The author need not seek justification of including R&E in the model to a single technology.

The *F*-test statistics reported in the table giving estimates for the distributed lag models using various lags give the impression that the F-test is for overall regression whereas the author used it to test the validity of restrictions imposed. This should be removed from the table and stated while discussing the restrictions and their testing.

The author has included dummy variable (D1) to capture the influence of abnormal (bad) agriculture years but has not made it explicit that value of 1 was assigned to bad years or otherwise. This should be made clear to understand the sign of the coefficient for this dummy variable.

I fully agree with the author that R&E funding need to be enhanced many folds than its present level in Pakistan. In addition to enhanced allocation of funds towards R&E, there is a need to optimally allocate the available funds among various disciplines. Currently, most of the budget allocation is meant for research on crops (mainly for the major crops) whereas disproportionately small amounts are allocated to research on livestock (presently the largest contributor to the value added in agriculture), horticultural crops, natural resource management, and fisheries etc.

Moreover, research system in Pakistan offers limited career growth opportunities and little financial incentives even to the highly qualified scientists. Most of the institutions lack access to quality literature and modern lab equipment to undertake quality research. The scientists have inadequate links with the international and national research and educational institutions, entrepreneurs, extension agents, and the farmers. There is rapidly aging profile of agricultural scientists and a continuous brain drain from the system. The science gap is widening due to fast moving scientific development internationally. The present national research system is ill-equipped to meet even the present challenges not to speak of 2020 and beyond. Pakistan must introduce a more knowledge-intensive agricultural research system that focus on technological innovations at the system level and has access to modern biological sciences.

The discussion of results in more detail would help in improving the readability of the paper. Some of the references listed are not cited anywhere in the paper and some of the cited studies are not listed in the references. Also dates for some of the cited studies differ from those given in the references. All these need to be corrected.

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