Impact of Public Sector Investment on TFP in Agriculture in Punjab, Pakistan

Nasir Nadeem
Assistant Director Planning,
Directorate of Agriculture Engineering Multan, Pakistan.
Email of corresponding author: nasir_nadeem2001@yahoo.com

Khalid Mushtaq
Assistant Professor in the Department of Agricultural Economics,
University of Agriculture, Faisalabad, Pakistan.

P.J. Dawson
Reader in the School of Agriculture, Food and Rural Development,
Newcastle University, Newcastle upon Tyne, UK.

Abstract:
Agricultural productivity growth in underdeveloped countries is an important long-run source of real income growth and better living standards, and different sources of productivity have been identified in the empirical literature. In this study, we examine the relationship between productivity in agriculture and investments in agricultural research, extension, irrigation, and rural roads in Punjab province, Pakistan. Results show that agricultural research has a significant and positive impact on productivity with a long-run elasticity of 0.24; and the marginal internal rate of return to research is 27%. Public investments in agricultural extension, rural roads, and irrigation are also significant. Granger-causality tests show a unidirectional relationship from research to productivity.

Keywords: Agricultural Productivity; Agricultural Research; Pakistan

I. Introduction
In underdeveloped countries in particular, agricultural productivity from public investment in research, extension, human capital and infrastructure is important, particularly when there are diminishing factor returns and the expansion of cultivated land is constrained. During the Green Revolution, most countries in Asia experienced technological change and agricultural productivity grew. Among different types of agricultural expenditures, agricultural research and development (R&D) is the most important for growth in agricultural and food production (Evenson and Rosegrant, 1993). The share of total government expenditure on agriculture in development programmes provides important information about whether agriculture receives biased treatment. Several studies have shown that investments in agricultural R&D, education and extension have a high payoff in many underdeveloped countries but it is neglected with relatively few resources and this impacts on productivity and profits (Evenson, 1984). Khan and Akbari (1986) observe that many underdeveloped countries rely largely on imported technology from more developed countries; they engage in adaptive research and particularly for grain and fiber crops.
Numerous empirical studies have explored the relationship between public investment and agricultural productivity using different methodologies. Most focus on investment in agricultural research, agricultural extension and their combined effect. Examples include Chavas and Cox (1992), Fernandez-Cornejo and Shumway (1997), Makki et al. (1999), Fan (2000) and Fan et al. (2000, 2004), Pratt and Fan (2010).

A key focus is the importance of public investment (other than agricultural research and extension) on agricultural productivity. The impact of education, rural roads, rural market, irrigation and public infrastructure has been examined *inter alia* by Griliches (1964) and Fan et al. (2004). Few studies examine causality between agricultural productivity and agricultural research but exceptions include Pardey and Craig (1989) and Makki et al. (1999), and the consensus is that causality runs from research to productivity.

Pakistan’s agriculture is a dominant sector in terms of value added, employment and exports and it has grown rapidly since the 1960s at around 4% per annum (Ali, 2004). Public investment in agriculture however has declined. In relation to the total development expenditure, the share of agriculture and irrigation declined from 52% in the second Plan of 1960-65 to 18% in the 10-year perspective Plan of 2001-2011 (Government of Pakistan, 2007).

Few attempts have been made to explore the relationship between agricultural research and agricultural output or total factor productivity (TFP) in Pakistan. Khan and Akbari (1986) examine the relationship between agricultural output and agricultural research and extension in a production function framework with a 10-year lag structure and found a rate of return to agricultural research of 36%. Nagy (1991) estimated the marginal internal rate of return to agricultural research and extension in Pakistan at 65%, again with a 10-year lag. Evenson and Bloom (1991) found a high rate of return to investment in agriculture. Rosegrant and Evenson (1993) measured the marginal rate of return of 58%, 39%, 51% for crop-specific research, general research and that specific to high yielding varieties. Ali (2005) estimated the marginal internal rate of return to expenditure on research and extension at 88%. Kiani (2008) calculated the impact of various investment variables on agriculture productivity. The results indicate that agricultural research expenses, number of tractors, and tube-wells have positive and significant impact on TFP in the crops sub-sector. The results also concluded attractive marginal rates of return to investments in agricultural research in Punjab.

The objectives of this study are to examine the impact of public sector investment on agricultural TFP in Punjab province. We estimate the returns to agricultural research and examine the causal relationship between agriculture research, investment and TFP. The paper is organized as follows: Section 2 explains our methodology, Section 3 discusses the data and results, and Section 4 concludes and draws some policy conclusions.

---

1 Rosegrant and Evenson’s results do not find support from other studies and Khan (1997) cites their use of unreliable data. In particular, Rosegrant and Evenson do not explain the sources of their panel dataset which covers 35 districts for 1955-85, yet official documents do not report data at this level of disaggregation for many of the inputs used in their analysis.
II. Material and Methods

The relationship between productivity and research is generally explored by the TFP decomposition method which comprises of two stages. We first estimate the TFP index and then regress this against research investment and other variables. Thirtle and Bottomley (1989) divided inputs into conventional and non-conventional inputs. The former, which are used in the first step, include land, labor, capital, chemicals and other inputs normally used in the production process. The latter, which are used in the second step, includes research and extension.

The relationship between TFP and investment in agricultural research, agriculture extension, irrigation, and rural roads is specified as:

$$\text{TFP}_t = A \prod_{j=0}^{k} \text{RES}_{t-j} \cdot \text{EXT}_{t-j} \cdot \text{IRR}_{t-j} \cdot \text{RRE}_{t-j} \cdot D \cdot e^u,$$  \hspace{1cm} (1)

where TFP$_t$ is the total factor productivity index of agriculture in year $t$, $A$ is a constant, RES, EXT, IRR and RRE are expenditures on agricultural research, agricultural extension, irrigation, and rural roads, $D$ is dummy variable to capture the influence of weather, floods etc., $\alpha$, $\beta$, $\gamma$, $\delta$, and $\epsilon$ are parameters to be estimated, and $u$ is an error term with the usual properties.

In (1), RES$_{t-j}$ are the lagged values of expenditure on agricultural research, that is, for $j=0, \ldots, k$ are the partial productivity coefficients of research investment in period $t-j$. A critical issue is the determination of lag length. Pardey and Craig (1989) argue that it takes a long time to capture the impact of research on agriculture production and Alston, et al. (1998) claim that knowledge generated from research investment might never disappear. However, given the nature of agriculture production and the age of agricultural research in Pakistan, shorter lags may be appropriate. First, Pakistan's and especially Punjab's research system is young compared to more advanced countries. Prior to 1960, research investment and research capacity were very limited and it might be argued that this has a negligible impact on today's production. Second, almost all agricultural related research is adaptive (Khan and Akbari, 1986). The varieties which played the major role in enhancing agricultural productivity were maxi-pak wheat and basmati rice developed at the International Wheat and Maize Institute in Mexico and the International Rice Research Institute in the Philippines. The adoption of these varieties with increasing requirements of irrigation and fertilizer resulted in increased yield and 97% of Pakistan's wheat area is now under modern varieties (Government of Pakistan, 2007). The lag structure in (1), in terms of its shape, order and length, is usually decided on the basis of prior empirical evidence. Different lag patterns have been used in the literature and the choice depends upon the most satisfactory fit on the basis of statistical criteria. The major objective of applying the lag structure in distributed lagged models is to reduce the number of parameters to avoid degrees of freedom and multicollinearity problems (Pardey and Craig, 1989). To select lag length, we estimate (1) with 1-15 lags for RES and we choose that which maximizes $R^2$. We then use the Almon (1965) polynomial lag scheme. Endpoint restrictions are also imposed on the $\beta$s by assuming that the current and the $k^{th}$ lag coefficients are zero that is the values of the current period as well as the

---

2 Griliches (1979) first observed that the lagged effect of R&D on output could reasonably be expected to follow a bell-shaped distribution. Almon's lag scheme has the ability to model this inverted U-shaped research diffusion process.
kth period of RES do not have an impact on TFP (Gujarati, 2003, pp.695). We use a second degree polynomial following Thirtle and Bottomely (1989) and Schimmelpfennig and Thirtle (1999).

We assume that agricultural extension is a short-run variable following Yee, et al. (2002), since unlike agricultural research it can be expected to have an almost immediate impact on agricultural productivity. Expenditures on irrigation and rural roads are also included as short-run determinants of TFP following Fan (2000) and Schimmelpfennig and Thirtle (1999).

To measure the internal rate of return associated with research investment, we use the standard methodology widely used in the literature, for example by Nagy (1991) and Fernandez-Cornejo and Shumway (1997). The marginal internal rate of return is calculated from the estimated elasticities in (1), that is: \[ \eta_i = \frac{\partial \log \text{TFP}_i}{\partial \log \text{RES}_{i-1}} = \frac{\partial \text{TFP}_i}{\partial \text{RES}_{i-1}} \cdot \frac{\text{TFP}_i}{\text{RES}_{i-1}}. \] (2)
Rearranging (2) gives: \[ \frac{\partial \text{TFP}_i}{\partial \text{RES}_{i-1}} = \frac{\eta_i (\text{TFP}_i / \text{RES}_{i-1})}. \] (3)
Replacing \( \frac{\text{TFP}_i}{\text{RES}_{i-1}} \) by their means and using discrete approximations gives:
\[ \frac{\Delta \text{TFP}_{t-i}}{\Delta \text{RES}_{t-i}} = \eta_i (\frac{\text{TFP}_{t-i}}{\text{RES}_{t-i}}). \] (4)
Productivity change can be converted into a change in the value of output when both sides of (4) are multiplied by the average increase in the net value of output (Y) caused by a one index point increase in productivity:
\[ \frac{\Delta \text{TFP}_{t-i}}{\Delta \text{RES}_{t-i}} \frac{\Delta Y_i}{\Delta \text{TFP}_t} d\text{TFP}_t = \eta_i (\frac{\text{TFP}_{t-i}}{\text{RES}_{t-i}}) \frac{\Delta Y_i}{\Delta \text{TFP}_t} d\text{TFP}_t. \] (5)
From (5), the value marginal product of research in period (t-i) is:
\[ \text{VMP}_{t-i} = \frac{\Delta Y_i}{\Delta \text{RES}_{t-i}} = \eta_i (\frac{\text{TFP}_{t-i}}{\text{RES}_{t-i}}) \frac{\Delta Y_i}{\Delta \text{TFP}_t}. \] (6)
The value of output \( \frac{\Delta Y_i}{\Delta \text{TFP}_t} \) and \( \frac{\text{TFP}_{t-i}}{\text{RES}_{t-i}} \) are calculated as averages, \( \eta_i \) varies over the lag period providing a series of marginal value products resulting from a unit change in research expenditures. The marginal internal rate of return is calculated from these annual flows of value benefits from a unit change in research investment as:
\[ \sum_{n=0}^{\infty} \left( \frac{VMP_{t-n}}{(1+r)^n} \right) - 1 = 0 \] (7)
Although regression analysis examines the dependence of one variable on another, it does not establish causation. Accordingly and following Gujarati (2003, pp.697), we examine Granger-causality between TFP and RES by estimating:

---

3 These equations are heavily drawn from Ali (2005).
We used the same lag length as found in the estimated model in (1). In (8) for example, Granger-causality is tested by using an F-test where the null hypothesis is: $\beta_{1i} = 0$ for $i = 1, \ldots, n$. RES Granger-causes TFP if $\beta_{1j} \neq 0$ in (8); TFP Granger-causes RES if $\beta_{2j} \neq 0$ in (9); and there is bidirectional causality if $\beta_{1j} \neq 0$ and $\beta_{2j} \neq 0$ in (8) and (9).

### III. Results and Discussion

Data on research consist of both development and non-development expenditures. Annual development data were collected for 1970-2005 from Annual Development Plans while non-development data were collected from Annual Budget Copies (Government of Punjab). Data on all investments were collected on the basis of actual utilization rather than budget allocation because there is often a considerable difference. Expenditure on irrigation (both development and non-development) is composed of expenditure on irrigation work, drainage and reclamation, survey and investigation, flood works and small dams. Data on rural road expenditure are available only for 1985-2005; those for 1970-1984 are calculated on the basis of the percentage share of the rural roads in the total provincial roads. In particular, expenditure on rural roads is calculated as the per kilometer expenditure multiplied by one fifth of the expenditure on total rural road length, that is we assume that cost per unit of rural roads is one fifth that of urban roads. 


We estimate the model in (1) which is linear in logarithms and results are presented in Table 1. Two models are estimated: Model I omits the weather dummy while Model II includes it. In Model II, the sign on D is negative as expected but it is insignificant.5 The results in Models I and II are robust to the inclusion of D and the former is preferred. Model I shows that all variables are significant at least at the 10% level, and the signs of the coefficients are as expected. It is a reasonable fit with more than 95% of the variation in TFP being explained by the regressors. The Durbin-Watson (DW) statistic implies that serial correlation is absent. Ramsey's specification test is applied to test the functional form; $F=0.50$ (p-value: 0.82) and the null hypothesis that the model is correctly specified, cannot be rejected.

In Model I, the coefficient on agricultural extension (EXT) is 0.15 which implies that a 1% increase in EXT increases TFP by 0.15% and accords with a priori expectations. The agricultural extension wing of the Agricultural Department has the largest network and number of employees that extend advisory services to farmers (Jalvi, 1990). The contribution of extension in Punjab appears significant. This supports the

---

4 This ratio is used by Fan et al. (2004).

5 Nagy (1991) examined the relationship between research and productivity in Pakistan and found weather to be insignificant, as did Ali (2005) with the wrong sign.
important role played by agricultural extension services in providing information and technology-transfer to farming communities and demonstrates its successes during the Green Revolution of the 1960s (FAO, 2004). A number of extension programmes have been initiated by the Government since independence e.g. crop maximization programs, Training and Visit and Barani Area Development Programme, Farmers Training Programme and Farmers Field Schools etc. These aided the adoption of new technologies and improved resource efficiency. Our result supports those from elsewhere for Pakistan, including Ahmed et al. (1999) and Khan and Chaudhry (1987) who have shown a positive impact of extension on agricultural productivity. Our result also supports international evidence from inter alia Rosegrant and Evenson (1992).

Table 1: Results of the Productivity Model - Dependent Variable: TFP_t

<table>
<thead>
<tr>
<th>Variables</th>
<th>Model I</th>
<th>Model II</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>-0.64</td>
<td>-0.56</td>
</tr>
<tr>
<td></td>
<td>(-0.50)</td>
<td>(-0.44)</td>
</tr>
<tr>
<td>EXT_t</td>
<td>0.15*</td>
<td>0.15*</td>
</tr>
<tr>
<td></td>
<td>(4.75)</td>
<td>(4.65)</td>
</tr>
<tr>
<td>IRR_t</td>
<td>0.31**</td>
<td>0.30**</td>
</tr>
<tr>
<td></td>
<td>(1.82)</td>
<td>(1.70)</td>
</tr>
<tr>
<td>RRE_t</td>
<td>0.13*</td>
<td>0.13*</td>
</tr>
<tr>
<td></td>
<td>(1.99)</td>
<td>(2.08)</td>
</tr>
<tr>
<td>D_t</td>
<td>-0.01</td>
<td>(-0.07)</td>
</tr>
</tbody>
</table>

Lag coefficients of RES

<table>
<thead>
<tr>
<th></th>
<th>Model I</th>
<th>Model II</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0.011</td>
<td>0.012</td>
</tr>
<tr>
<td>1</td>
<td>0.020</td>
<td>0.020</td>
</tr>
<tr>
<td>2</td>
<td>0.026</td>
<td>0.027</td>
</tr>
<tr>
<td>3</td>
<td>0.031</td>
<td>0.031</td>
</tr>
<tr>
<td>4</td>
<td>0.033</td>
<td>0.033</td>
</tr>
<tr>
<td>5</td>
<td>0.033</td>
<td>0.033</td>
</tr>
<tr>
<td>6</td>
<td>0.031</td>
<td>0.031</td>
</tr>
<tr>
<td>7</td>
<td>0.026</td>
<td>0.027</td>
</tr>
<tr>
<td>8</td>
<td>0.020</td>
<td>0.020</td>
</tr>
<tr>
<td>9</td>
<td>0.011</td>
<td>0.012</td>
</tr>
</tbody>
</table>

Sum of lag coefficients of RES 0.24* 0.25* (3.15) (3.15)

F-statistic 108.32 84.87

R^2 0.952 0.952

\( \bar{R}^2 \) 0.943 0.942

DW-statistic 2.12 2.08

Ramsey (F-statistic) 0.50 0.44

[0.82] [0.65]

Notes: 1. * and ** denote significance at 5% and 10% respectively.
   i. Values in parenthesis are t-ratios.
   ii. Values in square brackets are p-values.

The estimated coefficient of irrigation (IRR) is 0.31 and is significant at the 10% level. Presently, the Indus basin irrigation system is the largest contiguous irrigation system in the world covering an area of 14m hectares and includes three major reservoirs at Mangla, Terbala and Chashma. There are 19 barrages and 12 link canals, and the length of inter-river link canals is about 850 km. There are 45 main canal commands, of
which 24 are located in Punjab, covering 8.41m hectares (Government of the Punjab, 2007). Our result is consistent with the findings of Binswanger et al. (1993), Fan (2000) and Fan et al. (2000).

The estimated elasticity of the expenditure on rural roads (REE) is 0.13 and is significant at the 5% level. Thus a 1% increase in the investment on infrastructure such as rural roads increases TFP by 0.13%. This result supports other studies: Leinbach (1983) concludes that road development to farms contributes to higher productivity; Binswanger et al. (1993) and Ashok and Balasubramanian (2006) conclude that easier access to markets, technology and better roads raises farm and non-farm production by providing accessibility to relevant inputs at lower cost; and Fan et al. (2000) found a positive and significant impact of rural infrastructure investment on TFP.

The long-run elasticity of agricultural research (RES) is 0.24 and is highly significant. Thus, a 1% increase in research investment increases productivity by 0.24%. A wide network of institutional infrastructure is present in Punjab for agricultural research. Following independence, there were few research institutes in Pakistan, but substantial progress had been made since. Today there are 163 public agricultural research institutes in Pakistan and most are located in Punjab province. Moreover, more than 3000 professionals are working in these institutes (Khalid and Khan, 1993). Pakistan also has five agricultural universities; two are located in Punjab province; and there are a number of agricultural colleges. The individual coefficients of lagged research indicate the distribution of this impact over time. We use an F-test to test restrictions from restricting the coefficients to lie on a second degree polynomial: F=1.70 (p-value: 0.21) and we do not reject the null hypothesis that the second degree of polynomial is appropriate. An F-test on the endpoints restrictions of the distribution gives F=2.50 and we do not reject the null hypothesis that these restrictions are valid. Table 1 also shows that the lags of research coefficients are significant; they are symmetrically U-shaped as their values first increase and then after reaching a maximum, diminish. Our results support other studies like Fan (2000) and Ali (2005).

The marginal internal rate of return to research from productivity elasticities is 27%. This value similar to those of Khan and Akbari (1986) whose estimate is 36%, and Makki et al. (1999) and Chavas and Cox (1992) whose estimates are of 27-28%. The marginal internal rate of return in the Punjab is higher than that from alternative investments and the Punjab agricultural research system is productive.

Pair-wise Granger-causality tests are conducted between agricultural research and TFP where the variables are in logarithmic form. To test causality from RES to TFP, F=3.30 [p-value: 0.05]; and to test causality from TFP to RES, F=1.40 [0.31]. We conclude therefore that there is a unidirectional causality from RES to TFP, and agricultural research has a positive and significant impact on agricultural TFP. Conversely, TFP does not significantly contribute towards agricultural research.

IV. Conclusion and Recommendations

This paper provides strong evidence of a significant relationship between agricultural productivity and agricultural research investment in Punjab province in Pakistan. The estimated marginal internal rate of return is 27%. This relatively high rate of return suggests that there has been under-investment in agricultural research. In
addition, expenditures on extension, irrigation and rural roads significantly determine agricultural productivity. Granger-causality tests show that there is a unidirectional relationship from agricultural research to agricultural productivity.

The empirical literature suggests that a major source of technological change in agriculture is R&D. This study also concludes that investment in agricultural R&D is a major contributor in explaining the variation in productivity in Punjab agriculture. We conclude that there has been an under-investment in agricultural R&D and concur with Government of Pakistan (1988), Evenson and Bloom (1991) and Ali (2005). It is recommended that more funds should be allocated to agricultural R&D so that agricultural research institutions can play a more effective role. Moreover, the private sector should also be encouraged to invest in agricultural R&D by eliminating legal, administrative and bureaucratic constraints. The long-run impact of research on agricultural productivity implies that stable investment in R&D would partly insulate agriculture from shocks in aggregate productivity. We also advocate investment in agricultural extension, irrigation and rural roads infrastructure because each has its own importance and are closely linked with the objectives of increasing agricultural productivity and reducing poverty in rural areas of the Punjab province.

References


