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***Distinguished Lecture***

# Research, Extension, and Information: Key Inputs in Agricultural Productivity Growth

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The objective of this paper is to examine how economists have perceived the contributions of agriculture to the economic development process and then to present the case for the critical role that research, extension, and information can play in agricultural productivity growth and thus in economic development, particularly in low income countries. After a brief presentation of the framework commonly used to examine productivity growth, a distinction is made between technological change and technical efficiency. This distinction is crucial for policy purposes because the major impetus behind technological change are research and development, while education and experience are critical to improving managerial capabilities to make efficient use of a given technology. Empirical findings concerning the returns on agricultural research, with special attention to studies that have focused on Pakistan, are discussed. The paper then offers an overview of alternative methodologies available to measure technical efficiency, summarises the empirical literature, and finally focuses on studies dealing with Pakistani agriculture.

Once it is established that improvements in technical efficiency could contribute significantly to increases in farm output and income, the discussion moves to some issues that have implications for the measurement and potential improvement of farm efficiency. An overview of a model of privatised extension services, currently being applied in some Latin American countries and which could have some relevance to conditions in Pakistan and elsewhere, is provided. The paper ends with the contention that significant improvements are needed in the collection and organisation of farm production data if we are to advance our understanding of the drivers of productivity growth at the farm level.

## 1. INTRODUCTION

A remarkable feature of our time is the consensus regarding the importance of market forces in the economic growth of rich and poor countries alike [Crook (1997)]. This consensus has not escaped agriculture, as demonstrated by the policy reforms that many countries have adopted. These policies gathered momentum during the Uruguay Round of GATT and have sought to liberalise domestic farm prices and to integrate domestic markets into the global economy [Baffes and Meerman

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(1997)]. Despite these changes, poverty alleviation continues to be a major unfulfilled task. Hence, a significant challenge facing policy-makers in many less developed countries (LDCs) is to ensure that the millions of subsistence farmers who become integrated into the market economy can cope with the rigours imposed by international competition [Garrett (1997) and Timmer (1997)].

The objective of this paper is to examine how economists have perceived the contributions of agriculture to the economic development process and then to present the case for the critical role that research, extension, and information can play in agricultural productivity growth and thus in economic development, particularly in low-income countries. In Section 2 we review the role that agriculture can play in the process of economic development. The third section provides an overview of a framework for examining productivity growth and spells out the difference between technological change and technical efficiency. The fourth section starts with some brief comments on alternative methodologies used to measure the rates of return on investments in agriculture (and extension) and then reviews empirical findings concerning these returns with special attention to studies that have focused on Pakistan. The fifth section provides an overview of alternative methodologies available to measure technical efficiency, gives an overview of the empirical literature, and then focuses on studies dealing with Pakistani agriculture. The sixth and last section presents concluding remarks.

## 2. AGRICULTURE AND ECONOMIC DEVELOPMENT

Agriculture plays an important role in the economic transformation of many countries, particularly in LDCs. The economic transformation is the process by which the relative importance of agriculture in a country's economy tends to decrease over time in terms of the share of employment and income generated by this sector [Timmer (1988)]. This process has been characterised by Johnston (1970) as one of the most robust empirical regularities in economics.

Table 1 presents the types of data that are commonly used to document the economic transformation for a group of 20 countries for the years 1965, 1975, 1985, 1995, and 2000. These countries are separated into three groups, High-income (HIC), Middle-income (MIC), and Low-income (LIC), according to the World Bank classification for 2000.

To illustrate the general relationships that are expected from the economic transformation perspective, we will focus on the years 1975 and 1995 and on three countries—Canada, Mexico, and Pakistan—one from each income category (see Table 1, Figure 1). In 1975 we observe that agriculture's share of GDP is 4 percent, 8 percent, and 30 percent for Canada, Mexico, and Pakistan, respectively. In 1995, this share remains unchanged for the first two countries but it decreases to 26 percent in Pakistan. For these three countries—in the same order, the share of agriculture in total employment is 7 percent, 40 percent, and 57 percent in 1975 and

Table 1

*Descriptive Statistics for the Agricultural Sector in Selected Countries*

| | 1965 | | | | 1975 | | | | 1985 | | | | 1995 | | | | 2000 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | GNP/ | Agriculture Share (%) | | | GNP/ | Agriculture Share (%) | | | GNP/ | Agriculture Share (%) | | | GNP/ | Agriculture Share (%) | | | GNP/ | Agriculture Share (%) | | |
| Country[2] | CAP[1] | GDP | Emp. | Exp. | CAP | GDP | Emp. | Exp. | CAP | GDP | Emp. | Exp. | CAP | GDP | Emp. | Exp. | CAP | GDP | Emp. | Exp. |
| **HICs** | | | | | | | | | | | | | | | | | | | | |
| Australia | 1,943 | 10 | 10 | N.A.[3] | 6,360 | 6 | 7 | 41.8 | 11,370 | 4 | 6 | 33.6 | 17,500 | 3 | 6 | 26.7 | 20,050 | 3 | N.A. | 24.1 |
| Canada | 2,634 | 5 | 10 | | 7,710 | 4 | 7 | 9.7 | 13,250 | 3 | 5 | 11.2 | 19,970 | 4 | 3 | 6.8 | 19,320 | – | | 5.7 |
| Japan | 920 | 9 | 26 | | 4,940 | 6 | 15 | 0.5 | 10,070 | 3 | 9 | 0.4 | 39,640 | 2 | 7 | 0.4 | 32,230 | 2 | | 0.3 |
| New Zealand | 2,123 | – | 13 | | 4,360 | 11 | – | 73.8 | 7,010 | 11 | – | 56.2 | 14,340 | 11 | – | 32.2 | 13,780 | – | | 44.7 |
| USA | 3,447 | 3 | 5 | | 8,070 | 3 | 4 | 21.6 | 16,270 | 2 | 3 | 19.2 | 24,740 | 2 | 3 | 10.2 | 30,600 | 2 | | 7.2 |
| **MICs** | | | | | | | | | | | | | | | | | | | | |
| Argentina | 740 | 17 | 18 | | 2,680 | 10 | 14 | 69.6 | 3,050 | 13 | 13 | 75.3 | 7,220 | 6 | 12 | 49.4 | 7,600 | 5 | | 41.1 |
| Brazil | 228 | 19 | 48 | | 1,170 | 12 | 41 | 53.0 | 1,580 | 13 | 29 | 41.5 | 2,930 | 11 | 23 | 28.8 | 4,420 | 9 | | 23.2 |
| Bolivia | 195 | 21 | 54 | | 360 | – | 49 | 15.4 | 470 | 27 | – | – | 800 | 18 | – | 20.3 | 1,010 | 18 | | 35.6 |
| Chile | 693 | 9 | 27 | | 920 | 7 | 22 | 10.3 | 1,410 | 7 | 20 | 9.3 | 4,160 | 8 | 19 | 15.9 | 4,740 | 8 | | 15.7 |
| Egypt | 144 | 29 | 55 | | 310 | 22 | 49 | 49.0 | 580 | 20 | 46 | 10.9 | 790 | 20 | 43 | – | 1,400 | 17 | | 10.6 |
| El Salvador | 266 | 29 | 59 | | 470 | 38 | 50 | 71.4 | 810 | 19 | 40 | 71.9 | 1,320 | 14 | 36 | 48.1 | 1,900 | 10 | | 21.5 |
| Guatemala | 291 | – | 64 | | 570 | – | 64 | 72.4 | 1,250 | 27 | 64 | 76.5 | 1,340 | 25 | 64 | 45.5 | 1,660 | 23 | | 59.9 |
| Honduras | 205 | 27 | 68 | | 400 | 32 | 61 | 79.0 | 790 | 27 | 49 | 64.1 | 600 | 21 | 41 | 49.9 | 760 | 18 | | 22.4 |
| Mexico | 467 | 14 | 50 | | 1,360 | 8 | 40 | 32.5 | 2,080 | 11 | 37 | 8.1 | 3,320 | 8 | 34 | 6.1 | 4,400 | 4 | | 4.6 |
| Thailand | 130 | 35 | 82 | | 360 | 23 | 75 | 67.9 | 800 | 17 | 70 | 45.0 | 2,740 | 11 | 46 | 12.3 | 1,960 | 10 | | 10.6 |
| **LICs** | | | | | | | | | | | | | | | | | | | | |
| Bangladesh | 75 | 53 | 84 | | 130 | 50 | 81 | 30.6 | 150 | 50 | 75 | 24.5 | 240 | 31 | 73 | – | 370 | 26 | | 1.8 |
| Indonesia | 36 | 59 | 71 | | 210 | 24 | 62 | 12.2 | 530 | 24 | 57 | 13.2 | 980 | 17 | 46 | 10.5 | 580 | 17 | | 8.0 |
| Nigeria | 99 | 53 | 72 | | 430 | 21 | 69 | 5.6 | 800 | 36 | 68 | 2.5 | 260 | 28 | 65 | 4.1 | 310 | 39 | | 1.7 |
| *Pakistan* | *100* | *40* | *60* | | *140* | *30* | *57* | *44.3* | *380* | *25* | *55* | *25.6* | *460* | *26* | *52* | *12.1* | *470* | *26* | | *11.7* |
| Senegal | 223 | 25 | 83 | | 380 | 24 | 82 | 33.9 | 370 | 19 | 79 | 30.9 | 600 | 20 | 77 | 24.3 | 510 | 18 | | 16.2 |

*Source:* Elaborated by the author based on World Bank (1986, 2002 and other years), and FAO (1985 and 1995).

[1] GNP per capita in Current US$.

[2] High-income, Middle-income and Low-income Countries according to World Bank (2002).

[3] N.A.: Data for this column are not available.


**Fig. 1. Agricultural Shares of GDP, Employment, and Exports in 1975 and 1995 for Canada, Mexico, and Pakistan.**

3 percent, 34 percent, and 52 percent in 1995. The share of agricultural exports between the two years goes from 9.7 percent to 6.8 percent in Canada, 32.5 percent to 6.1 percent in Mexico, and from 44.3 percent to 12.1 percent in Pakistan. In sum, the data clearly show that agriculture becomes less important in terms of its contribution to GDP, employment, and exports as GNP per capita increases over time for a given country and across countries at a given point in time.

Two fundamental reasons explain the economic transformation: (1) the low-income elasticity of demand for food; and (2) the possibility of sharply increasing agricultural output with a constant or even a declining labour force [Johnston and Mellor (1961)]. The relative contribution of agriculture in a country's economy declines as income per capita increases because the share of the additional income devoted to food declines (i.e., Engel's Law). Moreover, as labour and land productivity increase, fewer resources are needed to produce a given level of food output.[1]

Timmer (1993) has argued that the drop in agricultural employment and the declining share of agriculture's contribution to GNP as economic growth proceeds have led influential economists to erroneously conclude that the farming sector does not play an important function in the development process. An implication of this view is that governments need not be concerned with providing a suitable policy environment for agriculture since this sector is destined to become increasingly irrelevant. Economists who have had a significant influence in the formulation of

[1]On average, in LDCs a peasant family produces enough food to feed itself and two other persons, while in most industrialised countries a farm family produces enough food to feed 50 individuals [World Bank (1986)].

policies that have discriminated against agriculture include Raul Prebisch, Hans Singer, Albert Hirschman and, indirectly, Arthur D. Lewis [Eicher and Staatz (1990)].

A key point used to justify the view that farming is not pivotal to development is that the terms of trade consistently evolve against agriculture and, therefore, public policy should focus on the promotion of investments in industry. Another contention is that agriculture lacks linkages (both forwards and backwards) with other productive sectors and thus it is not attractive as a source for increased economic activity. It has also been argued that agriculture can provide an unlimited quantity of workers to the industrial sector, most of whom have zero opportunity cost since they are redundant in the sense that their marginal productivity is zero.

Some economists have claimed that the low elasticity of supply for agricultural products justifies establishing artificially low prices for these products in order to benefit the urban population and thus promote industrial growth. Finally, among those that consider agriculture to be unimportant, some contend that key modern agricultural inputs (e.g., tractors) are indivisible, which makes the fostering of large-scale farming operations an important policy objective if costs are to be minimised [Eicher and Staatz (1990) and Schultz (1987)].

In response to the preceding negative views of the function of agriculture, Johnston and Mellor published an important paper in 1961, which marks a major change in development thought. In this paper, which has become a classic in the literature, these authors lay out the claim that the agricultural sector has a crucial and very positive role to play in the development process. First, Johnston and Mellor (1961) argue that agriculture must generate a food supply sufficient to satisfy a growing demand. If this objective is not fulfilled, then economic growth can be compromised. The annual growth in food demand $(D)$ is given by $D = p + ng$, where $p$ is the annual population growth rate, $g$ is the annual per capita income growth rate, and $n$ is the income elasticity of demand for food. The growth in $D$ is of special importance in LDCs given that the values for $p$ and $n$ tend to be relatively high.

A second task assigned to the agricultural sector by Johnston and Mellor is producing not only for internal consumption but also for export markets. In this fashion, this sector can contribute to the generation of foreign exchange, which can be devoted to importing capital goods that cannot be produced domestically.

The third function of agriculture is to transfer human resources from the farm to the city. Initially, this transfer is relatively easy if the farm labour supply is abundant and its marginal productivity is low. This notion is a major implication of the Lewis (1954) model. As the country develops, the transfer of workers must be accompanied by increases in labour productivity through farm mechanisation.

Another function of agriculture is to contribute to capital formation throughout the economy. Again, an important insight of the Lewis (1954) model is the explanation of why the rate of capital accumulation is critical in determining the pace at which the industrial sector can generate employment. A poor country that is trying to increase economic growth finds a major need to augment its capital in order to develop its infrastructure. The predominance of the agricultural sector in the economy clearly suggests its importance in generating the resources necessary to undertake such investments.

Finally, Johnston and Mellor (1961) contend that agriculture can be a significant stimulus to the industrial sector by acting as a major consumer of locally produced manufactured products. According to de Janvry (1987), empirical studies indicate that the expansion of the internal market has been the major contribution of agriculture to the growth in manufacturing.

Work by agricultural economists during the 1960s emphasised not only the role of the farm sector in the development process and the interdependence between agriculture and industry, but also the importance of understanding the determinants of agricultural growth in order to fully exploit its potential [Eicher and Staatz (1990)]. In the voluminous literature generated on this topic, it is important to single out the book entitled *Transforming Traditional Agriculture,* written by Schultz in (1964).

The fundamental argument set forth by Schultz is that peasant farmers behave as rational economic agents, in the neoclassical sense, and evaluate the costs and benefits associated with different production techniques. Over a long period of experimentation, given existing technology, these farmers have learned to allocate their resources efficiently. According to this argument, it is not possible to obtain noticeable gains in output by simply reallocating existing resources. In other words, Schultz contends that traditional peasant farmers, despite their low level of output per capita, are allocatively efficient. This idea is known in the literature as the "poor but efficient hypothesis". The corollary of this hypothesis is that gains in productivity in a traditional agricultural setting can only be obtained through technological change stemming from research along with higher educational levels of producers. In later papers, Schultz attributes the low level of investment in agricultural research in LDCs to public policies that systematically undervalue agriculture (1978; 1981).

More recently, Mellor (1986) has reexamined the function that agriculture should play in the economic development of LDCs. In this analysis, Mellor proposes an economic development strategy where the agricultural sector has a predominant role based on three fundamental elements. First, the rate of growth in agriculture must be swift and technological change must play a key role in this process. Second, domestic demand for agricultural products must increase rapidly, which is only possible if employment also grows rapidly. Finally, the demand for goods and services produced using low capital-intensive technologies must increase.

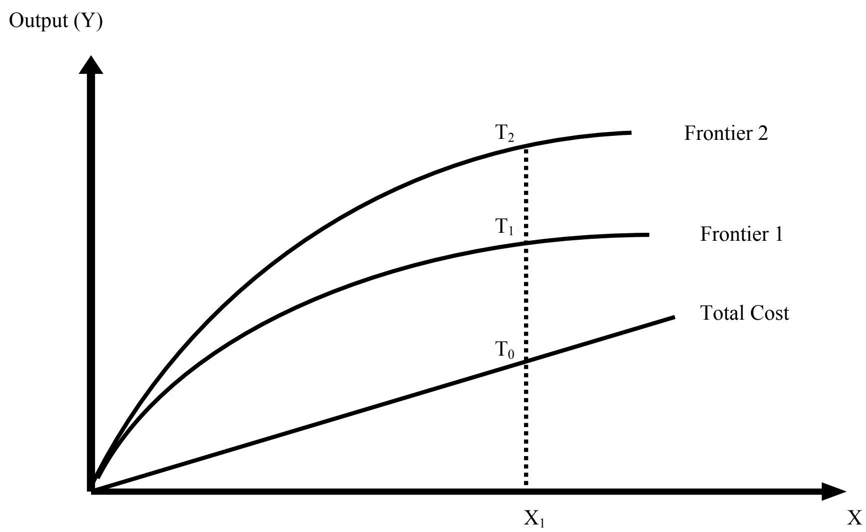
In sum, the conception of the role of agriculture in the process of economic development has experienced a marked evolution over the last several decades. It seems reasonable to assert that the current view is that this sector must continue to play a leading role in the economic growth of LDCs. Furthermore, current projections are that income and population growth will double the demand for agricultural products over the next 50 years, and much of this expansion will come from poor countries. The most challenging period will be the next 20 to 30 years, given that population as well as income will rise rapidly, particularly in the poorest countries. Therefore, substantial gains in productivity will be needed to keep up with the increase in demand [Ruttan (2002)].

Another factor that underscores the current importance of productivity growth in developing agriculture is the liberalisation of agricultural markets. There is agreement that trade liberalisation tends to enhance economic growth and could play a key role in the fight against poverty and food insecurity. However, there is also a realisation that globalisation could have [Pinstrup-Andersen (2002)] or is having [Oxfam (2002)] unfavourable effects on the most vulnerable countries and/or on specific sub-groups such as peasant farmers and poor urban consumers. This concern has been heightened by the passing of the US $73.5 billion 2002 Farm Bill in the United States, which authorises over 70 percent expansion in agricultural subsidies [von Braun, Wobst and Grote (2002)]. This action could very well trigger reactions by other countries and thus undermine trade negotiations.

In this environment, several analysts contend that increasing agricultural productivity through technical change and efficiency improvements, which historically have made very important contributions to economic growth [Ruttan (2002)], must be a major priority for low-income countries [Hazell and Haddad (2001)]. Moreover, Anderson (2002) argues that greater economic and technical assistance from the international community in "… agricultural research, rural education and health, and rural infrastructure may be important co-requisites of trade policy reform if developing countries are to be convinced that they would gain unequivocally from the Doha round [of trade negotiations]" (p. 17).

## 3. THE COMPONENTS OF PRODUCTIVITY GROWTH

Productivity growth can be decomposed into technological change and technical efficiency [Nishimizu and Page (1982)], where technological change can be defined as "…changes in the production process that come about from the application of scientific knowledge" [Antle and Capalbo (1988), p. 33]. By contrast, technical efficiency is defined as the firm's ability to produce maximum output given available resources and the state of technology [Farrell (1957)]. Figure 2 illustrates these two components of productivity growth.




$T_0$: Observed Output.
$T_1$: Frontier Output given $X_1$ and Frontier 1.
$T_2$: Frontier Output given $X_1$ and Frontier 2.

**Fig. 2. Output Growth Decomposition: Technological Change and Technical Efficiency.**

Despite the fact that technological change and technical efficiency are based on the production function methodology, as illustrated in Figure 2, the empirical measurement of these concepts has progressed largely on separate tracks. It is only in the last decade or so that the methodology introduced by Nishimizu and Page has been adopted by several researchers to decompose productivity growth into its two primary components [e.g., Fan (1991); Ahmad and Bravo-Ureta (1995) and (1996); Kalirajan, Obwona, and Zhao (1996); Ahmad and Ahmad (1998); Ahmad (2001)].

The distinction between technological change and technical efficiency is important not only for analytical reasons but also because the factors underlying each one of these sub-components are not the same. Technical efficiency can be interpreted as a relative measure of management ability, given the technology, while technological change leads to increases in productivity that arise from the adoption of new production practices. Consequently, gains in technical efficiency are derived from improvements in managerial ability which, in turn, are a result primarily of education, training, and experience. By contrast, the critical force propelling technological change is the investments in research and technology [Ahmad and Bravo-Ureta (1995)].

## 4. RETURNS TO AGRICULTURAL RESEARCH

The measurement of the returns to research (and, to a lower degree, extension) in agriculture has received a great deal of attention in the literature. A recent comprehensive meta analysis of this literature by Alston, *et al.* (2000) reports on 292 such studies. Historically, most of the agricultural research has been supported by government funds because agricultural research and extension are largely public goods that have a high social rate of return [Stiglitz (1987); Evenson and Pray (1991); Norton and Alwang (1993)]. More recently, as intellectual property rights have become better defined, the private sector has begun to play an increasingly significant role in agricultural research funding not only in the rich countries but also in the developing world, including Pakistan [Huffman and Evenson (1993); Ahmad and Nagy (2001)].

Several approaches have been used to measure the effects of past investments in agricultural research (and extension) on output, costs, or profits. Here we only provide a very general overview before we move on to discuss some of the key empirical results of this vast literature. The approaches used can be classified into parametric, non-parametric, index number procedures, and the imputation-accounting method.

The parametric approaches are based on an explicit functional form that ties inputs to outputs, where technology can be specified as a primal (production function) or dual (cost or profit function) model or in terms of output supply equations. The most popular specification, particularly for developing countries, appears to be production function models. The non-parametric procedures avoid the use of explicit functional forms, and the data are checked for consistency with axioms of behaviour (cost minimisation or profit maximisation). The calculations are typically done using linear programming techniques [Alston, Norton and Pardey (1995)].

The index number procedure relies on the estimation of total factor productivity (TFP) indexes calculated as the difference between an index of aggregate outputs and an index of aggregate inputs. Econometric procedures can then be used to determine the share of TFP that can be attributed to investments in agricultural research (and/or extension) among other factors [Alston, Norton and Pardey (1995)]. The imputation-accounting method requires that an invented technology is first identified. The costs of producing, developing, and distributing the inventions are then calculated, followed by estimates of the cost advantage to early adopters, the adoption pattern, and associated advantages. The advantages of adoption are then converted to a stream of aggregate net benefits, assuming reasonable market supply and demand functions. The present value of net benefits and internal rates of return are then calculated [Huffman and Evenson (1993)].

Empirical estimates of minimum and maximum rates of return to investments in agricultural research and/or extension in LDCs, derived from Alston, *et al.* (2000), are presented in Table 2. These estimates are presented here by type of commodity and region of the world including North America, Europe, Latin America, Africa, Australasia, and Global. These data show that the minimum rate of return for

Table 2

*Rates of Return to Agricultural Research and/or Extension: A Global Perspective*

| Region | Commodity | Research | | | Extension | | | Research and Extension | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | No.[1] | Min (%) | Max (%) | No. | Min (%) | Max (%) | No. | Min (%) | Max (%) |
| **North America** | Crops | 62 | 52.6 | 90.3 | 10 | 41.0 | 66.9 | 14 | 57.7 | 77.6 |
| | Anim. Prod.[2] | 42 | 56.6 | 69.9 | 1 | 81.0 | 99.0 | 6 | 16.6 | 19.6 |
| | Fruit Trees | 4 | 16.9 | 44.6 | – | – | – | 2 | 8.8 | 75.6 |
| | Forestry | 7 | 17.6 | 28.2 | – | – | – | 1 | 87.0 | 87.0 |
| | All Ag. | 18 | 35.1 | 96.6 | 7 | 60.3 | 144.3 | 11 | 34.4 | 76.6 |
| | *Average* | – | *35.8* | *65.9* | – | *60.8* | *103.4* | – | *40.9* | *67.3* |
| **Europe** | Crops | 1 | 17.3 | 18.6 | – | – | – | 1 | 17.0 | 18.0 |
| | Anim. Prod. | – | – | – | – | – | – | 1 | 75.7 | 122.2 |
| | All Ag. | 14 | 101.5 | 204.9 | – | – | – | 4 | 41.0 | 119.2 |
| | *Average* | – | *59.4* | *111.7* | – | – | – | – | *44.5* | *86.5* |
| **Latin-America** | Crops | 44 | 49.4 | 73.5 | 1 | 33.0 | 33.0 | 30 | 40.7 | 51.3 |
| | Anim. Prod. | 1 | 25.0 | 90.0 | 1 | 23.0 | 23.0 | 2 | 64.4 | 64.4 |
| | Fruit Trees | 2 | 19.4 | 60.5 | – | – | – | 2 | 22.8 | 27.8 |
| | Forestry | – | – | – | – | – | – | 3 | 41.4 | 47.9 |
| | All Ag. | 2 | 33.2 | 33.2 | – | – | – | 2 | 34.4 | 34.4 |
| | *Average* | – | *31.7* | *64.3* | – | *28.0* | *28.0* | – | *40.7* | *45.2* |
| **Africa** | Crops | 25 | 96.0 | 105.0 | 6 | 28.0 | 28.0 | 34 | 14.7 | 49.7 |
| | Forestry | – | – | – | – | – | – | 1 | 34.0 | 37.0 |
| | All Ag. | 3 | 114.0 | 121.0 | – | – | – | 3 | 80.7 | 80.7 |
| | *Average* | – | *105.0* | *113.0* | – | *28.0* | *28.0* | – | *43.1* | *55.8* |
| **Austral-asia** | Crops | 17 | 50.8 | 103.3 | 1 | 40.0 | 45.0 | 7 | 55.0 | 133.4 |
| | Anim. Prod. | 16 | 56.8 | 89.6 | – | – | – | 3 | 59.6 | 89.9 |
| | Fruit Trees | 4 | 81.6 | 106.7 | – | – | – | 2 | 57.3 | 111.6 |
| | Forestry | 9 | 73.5 | 103.2 | – | – | – | – | – | – |
| | All Ag. | – | – | – | – | – | – | 2 | 25.5 | 51.0 |
| | *Average* | – | *65.7* | *100.7* | – | *40.0* | *45.0* | – | *49.3* | *96.5* |
| **Asia**[3] | Crops | 63 | 66.5 | 724323 | 10 | 74.0 | 113.3 | 21 | 44.0 | 53.5 |
| | Anim. Prod. | 4 | 100.1 | 340.1 | – | – | – | – | – | – |
| | Fruit Trees | 4 | 75.0 | 85.0 | – | – | – | – | – | – |
| | All Ag. | 4 | 44.0 | 45.9 | 3 | 15.3 | 15.3 | 2 | 28.6 | 36.2 |
| | *Average* | – | *71.4* | *157.0* | – | *44.6* | *64.3* | – | *36.3* | *44.9* |
| **Global** | Crops | – | – | – | – | – | – | 8 | 46.8 | 66.2 |
| | Anim. Prod. | – | – | – | – | – | – | 2 | 44.0 | 51.0 |
| | *Average* | – | – | – | – | – | – | – | *45.4* | *58.6* |
| *Overall Average* | | – | *61.5* | *102.1* | – | *40.3* | *53.7* | – | *42.5* | *66.0* |

*Source:* Elaborated by the author, based on Alston, *et al.* (2000).

[1]Number of estimates by commodity and Region.

[2]Anim. Prod. includes livestock, dairy, and poultry.

[3]The 724,323 estimate is excluded from the averages.

research is 16.9 percent for fruit trees in North America, while the highest is 340.1 percent for Animal Products in Asia. For the extension estimates, the lowest rate of return is 23 percent for Animal Products in Latin America, while the highest is 144.3 percent for All Agriculture in North America. For studies that combine investments in Research and Extension, the lowest rate is 8.8 percent for fruit trees in North America and the highest is 133.4 percent for Crops in the Australasia Region. The bottom row in Table 2 indicates that the overall average returns (for all regions and commodities) range from 61.5 percent to 102.1 percent for Research, 40.3 percent to 53.7 percent for Extension, and from 42.5 percent to 66.0 percent for studies that combine Research and Extension.

To present a more detailed view of the rates of return for Pakistan, the studies conducted for this country are presented in Table 3. As shown in this Table, a total

Table 3

*Rates of Return to Agricultural Research, and Research and Extension in Pakistan*

| Study Type<br>Author(s),Year of Publication | Methodology | Commodity | Period | Min (%) | Max (%) |
|---|---|---|---|---|---|
| **Research** | | | | | |
| Pray (1978) | Imputation-Accounting | Other Crops | 1905-47 | 34.0 | 49.0 |
| | Imputation-Accounting | Other Crops | 1948-75 | 17.0 | 45.0 |
| Nagy (1991and 1984) | Parametric | All Crops | 1959-79 | 77.6 | 85.6 |
| | Index Numbers | Maize | 1964-81 | 23.0 | 23.0 |
| | Index Numbers | Wheat | 1964-81 | 68.0 | 68.0 |
| | Index Numbers | Wheat | 1964-81 | 81.0 | 81.0 |
| Azam, Bloom and Evenson (1991) | Index Numbers | All Crops | 1956-85 | 39.0 | 88.0 |
| | Index Numbers | Maize | 1956-85 | 46.0 | 46.0 |
| | Index Numbers | Other Crops | 1956-85 | 44.0 | 102.0 |
| | Index Numbers | Rice | 1956-85 | 89.0 | 89.0 |
| | Index Numbers | Wheat | 1956-85 | 76.0 | 76.0 |
| Iqbal (1991) | Parametric | Rice&Cotton | 1971-88 | 50.0 | 90.0 |
| Byerlee (1993) | Parametric | Wheat | 1978-87 | 22.0 | 27.0 |
| Collins (1995) | Imputation-Accounting | Wheat | 1972-86 | 60.0 | 71.0 |
| *Average Research* | | | | *51.9* | *67.2* |
| **Research and Extension** | | | | | |
| Nagy (1991 and 1984) | Parametric | All Crops | 1959-79 | 56.2 | 64.5 |
| | Index Numbers | Maize | 1964-81 | 19.0 | 19.0 |
| | Index Numbers | Wheat | 1964-81 | 64.0 | 64.0 |
| | Index Numbers | Wheat | 1964-81 | 58.0 | 58.0 |
| Nagy (1985) | Index Numbers | All Crops | 1959-70 | 65.0 | 65.0 |
| Khan and Akbari (1986) | Parametric | All Crops | 1955-81 | 321.0 | 724,323 |
| Collins (1995) | Imputation-Accounting | Wheat | 1972-86 | 28.0 | 51.0 |
| *Average Res. and Ext.* | | | | *48.4* | *53.6* |
| *Overall Average* | | | | *50.1* | *60.4* |

*Source:* Elaborated by the author, based on Alston, *et al.* (2000); Ahmad and Nagy (2001) and the original publications.

*Note:* The Khan and Akbari (1986) results are considered outliers and thus are excluded from the averages.

of eight studies were found for Pakistan, four reporting estimates for Research, two for Research and Extension, and two for both Research and Research and Extension. In total, 14 rates of return sets (minimum and maximum) are given for Research and six for Research and Extension. The commodity that has received most attention is wheat, with five sets of results for Research and three for Research and Extension, followed by maize with two sets of estimates and one set of estimates, respectively. In terms of methodology, the parametric approach has been the most widely used option.

The lowest rate of return for investments in research is 17.0 percent for Other Crops for the period 1948–1975. By contrast, the highest estimate is 102 percent for other crops for the period 1956–1985. For studies estimating rates of return for Research and Extension combined, the lowest figure is 19 percent for Maize for 1964–81 and the highest is 65 percent for All Crops for the period 1959–1970. If we look at the average for all studies focusing on Research, the minimum rate is 51.9 percent and the maximum is 67.2 percent. The averages for all studies that combine investment in Research and Extension are 48.4 percent (minimum) and 53.6 percent (maximum). The overall average for all studies yields a minimum of 50.1 percent and a maximum of 60.4 percent. A comparison of the average figures for all studies shown in Table 2 with those included in Table 3 indicates that the figures for Pakistan are, in general, somewhat lower than those for all countries/regions combined, but they are well within the ranges reported elsewhere. Moreover, the estimated figures are considerably higher than the 12 percent rate that has been traditionally required from investment projects funded by the World Bank [Gittinger (1982)]. Therefore, the evidence suggests that under-investment in agricultural research and extension is a generalised phenomenon and that Pakistan is not an exception in this regard.

## 5. TECHNICAL EFFICIENCY: MEASUREMENT AND MEASURES

As has been the case with the study of returns to research and extension, economists have made many advances in refining models to measure the efficiency component of productivity growth. This literature dates back to the seminal paper published by Farrell in (1957) which used the efficient unit isoquant to measure economic efficiency (EE), and to decompose this measure into technical (TE) and allocative efficiency (AE). In this model, TE can be defined as the firm's ability to produce maximum output given a set of inputs and technology. Allocative (or price) efficiency measures the firm's success in choosing the optimal input proportions, i.e., where the ratio of marginal products for each pair of inputs is equal to the ratio of their market prices. In Farrell's framework, economic efficiency is a measure of overall performance and is equal to TE times AE (i.e., EE = TE × AE).

The frontier function methodology has become a widely used tool in applied production analysis due mainly to its consistency with the textbook definition of a production, profit, or cost function (i.e., with the notion of maximisation or minimisation). This popularity is evidenced by the proliferation of methodological and empirical frontier studies over the last two decades as reviewed by Battese (1992); Bravo-Ureta and Pinheiro (1993) and Thiam, Bravo-Ureta, and Rivas (2001).

Frontier models can be classified into two basic types: parametric and non-parametric. Parametric frontiers, which require the specification of a particular functional form, can be separated into the deterministic and the stochastic. The deterministic model assumes that any deviation from the frontier is due to inefficiency, while the stochastic approach allows for statistical noise. Therefore, a fundamental problem with deterministic frontiers is that any measurement error, and any other source of stochastic variation in the dependent variable, is embedded in the one-sided component, making the resulting TE estimates sensitive to outliers [Greene (1993)]. The stochastic frontier production model addresses this sensitivity problem by incorporating a composed error structure with a two-sided symmetric term and a one-sided component. The one-sided component reflects inefficiency, while the two-sided error captures the random effects outside the control of the production unit. Figure 3 depicts the major differences between a parametric and a stochastic production frontier.

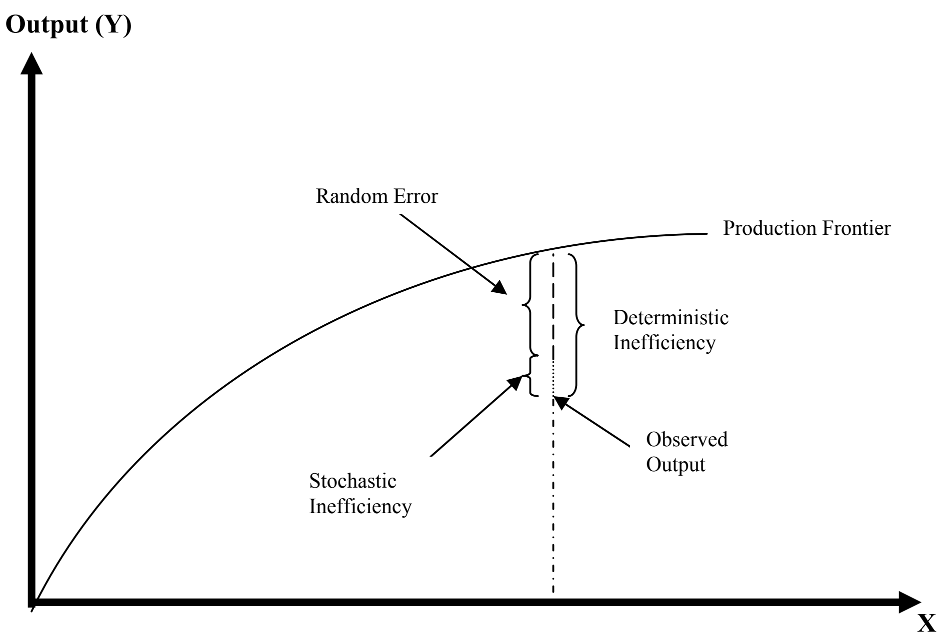



**Fig. 3. Stochastic and Deterministic Parametric Frontiers: A Graphical Representation.**

Econometric models for the estimation of efficiency can also be separated into primal and dual approaches, depending on the underlying behavioural assumptions that are made. The primal approach has been more common in frontier estimation, although the dual cost and particularly the profit function models have gained increasing attention in recent years [Kumbhakar (2001)]. The estimation of frontier functions can also be categorised, according to the type of data, as cross-section or panel data studies. The estimation of stochastic frontiers with panel data is very appealing because it can avoid several limitations present in cross-sectional studies [Schmidt and Sickles (1984)].

Non-parametric technical efficiency models, also referred to as data envelopment analysis (DEA), are based on mathematical programming techniques. The main feature of DEA methods is that they do not require the specification of a functional form. Nevertheless, a major drawback of these methods is that they are deterministic and thus affected by extreme observations. Another characteristic of DEA methods is the potential sensitivity of efficiency scores to the number of observations as well as to the number of outputs and inputs [Nunamaker (1985)].

Despite the significant advances in the frontier function literature, many methodological questions remain. Examples of these questions include the effect of functional form on parametric models, the lack of *a priori* justification for the selection of a particular distributional form for the one-sided inefficiency term in stochastic frontiers, potential simultaneous equation bias in primal models, the validity of dual models, particularly when profit maximisation is the maintained hypothesis, in the context of developing country agriculture. To what extent efficiency estimates are sensitive to model specification is a matter of on-going discussion. Authors like Coelli (1995) and Hjalmarsson, *et al.* (1996) have discussed the advantages and limitations of the different methodological approaches for the measurement of efficiency.

The empirical literature has focused largely on the measurement of TE and relatively little attention has been given to the measurement of EE and AE efficiency. Consequently, the discussion in this paper is limited to studies that have focused on the measurement of TE. Table 4 presents descriptive statistics according to methodological attributes for 126 published studies reported by Bravo-Ureta, Rivas, and Thiam (2001) in their meta-analysis of technical efficiency estimates using farm-level data. The total number of cases (observations) is 484 because some papers report multiple measures. Of this total number of observations, 135 are based on the deterministic and 349 on the stochastic models. The data show that the overall mean TE (OMTE) for all deterministic models is 75.2 percent as compared to the 77.3 percent for all stochastic models. A comparison between the parametric and the non-parametric estimates shows that the former are lower (71.9 percent) than the latter (80.2 percent), as would be expected on a theoretical basis.

Table 4

*Descriptive Statistics of Technical Efficiency (TE) Studies by Methodological Characteristics*

| Category | Deterministic Mean TE | | | Stochastic Mean TE | | | Overall Mean TE | | | Number |
|---|---|---|---|---|---|---|---|---|---|---|
| | Avg . | Max. | Min. | Avg . | Max. | Min. | Avg . | Max. | Min. | of Cases |
| **Approach** | | | | | | | | | | |
| Parametric | 71.9 | 95.9 | 44.6 | 77.3 | 89.1 | 55.2 | 76.3 | 90.1 | 53.3 | 429 |
| Non-parametric | 80.2 | 98.3 | 48.7 | | | | 80.2 | 98.3 | 48.7 | 55 |
| **Data** | | | | | | | | | | |
| Panel | 77.8 | 94.6 | 46.4 | 78.6 | 88.8 | 59.7 | 78.5 | 89.2 | 58.0 | 278 |
| Cross-sectional | 74.1 | 97.3 | 45.7 | 74.4 | 89.9 | 44.7 | 74.3 | 93.0 | 45.1 | 206 |
| **Functional Form** | | | | | | | | | | |
| Cobb-Douglas | 74.4 | 95.7 | 44.3 | 75.8 | 88.2 | 56.8 | 75.5 | 89.4 | 54.1 | 294 |
| Translog | 67.6 | 100.0 | 51.5 | 80.2 | 93.0 | 49.1 | 79.5 | 93.3 | 49.2 | 118 |
| Others | 64.6 | N.D. | N.D. | 85.0 | 85.0 | 85.0 | 65.8 | N.D. | N.D. | 17 |
| **Technology Representation** | | | | | | | | | | |
| Primal | 75.4 | 96.8 | 46.1 | 77.0 | 89.3 | 54.0 | 76.5 | 91.1 | 51.8 | 402 |
| Dual | 69.6 | 97.5 | 37.5 | 78.4 | 88.2 | 61.2 | 78.1 | 88.6 | 60.2 | 78 |
| **Total** | | | | | | | | | | |
| Average | **75.2** | **96.7** | **45.9** | **77.3** | **89.1** | **55.2** | **76.7** | **90.8** | **53.1** | |
| Number of Cases | | **135** | | | **349** | | | | | **484** |

*Source:* Bravo-Ureta, Rivas, and Thiam (2001).

Table 5 summarises the TE measures according to six geographical locations where the studies were conducted. The largest number of cases is for Asia (180), followed by Western Europe and Australia (137), North America (91), Latin America and the Caribbean (44), Eastern Europe (17), and Africa (15). The highest OMTE, when stochastic and deterministic studies are combined, is for Western Europe and Australia, at 83.2 percent; while the lowest is for Asia and Eastern Europe, at 72.5 percent for both groups. When the deterministic and stochastic OMTEs are calculated separately, Western Europe and Australia still exhibit the highest level, but there is some change in the rankings for the other regions.

Also displayed in Table 5 is the OMTE for all Low-income Countries (LICs) combined and for all High-income Countries combined (HICs). The LICs include Africa, Latin America, and the Caribbean, Asia (excluding Malaysia), and Ukraine. The HICs include Western Europe and Australia, North America, Malaysia, and Slovenia. The OMTE for the LICs, when the deterministic and the stochastic measures are combined, is 73.8 percent, while that for the HICs is 79.7 percent. By comparison, when one looks only at the deterministic cases, the OMTE for the LICs is 67.8 percent and 77.1 percent for the HICs, and for the stochastic cases the OMTE is 74.6 percent for the LICs and 82.0 percent for the HICs. Hence, the HICs consistently exhibit a higher level of average mean TE than the LICs.

Table 5

*Average Mean Technical Efficiency (TE) by Region and Type of Product*

| Region | No. of Cases | Overall Mean TE | | | Stochastic Mean TE | | | Deterministic Mean TE | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Avg. | Max. | Min | Avg. | Max. | Min | Avg. | Max. | Min |
| **Asia** | 180 | 72.5 | 86.9 | 52.0 | 73.5 | 86.2 | 53.0 | 64.3 | 94.6 | 42.1 |
| **W. Eur. and Austral.** | 137 | 83.2 | 98.6 | 56.5 | 83.8 | 98.1 | 58.4 | 82.0 | 100.0 | 53.9 |
| **North America** | 91 | 75.7 | 95.8 | 49.2 | 78.0 | 95.4 | 59.7 | 74.3 | 96.1 | 42.4 |
| **Lat.Am. and Carib.** | 44 | 78.0 | 89.7 | 59.5 | 78.3 | 87.9 | 62.3 | 76.4 | 100.0 | 43.3 |
| **Eastern Europe** | 17 | 72.5 | 95.3 | 48.5 | 71.5 | ND | ND | 75.0 | 95.3 | 48.5 |
| **Africa** | 15 | 75.3 | 95.5 | 37.5 | 78.6 | 95.9 | 42.8 | 53.5 | 93.5 | 13.8 |
| **LIC*** | 248 | 73.84 | 87.98 | 53.00 | 74.55 | 86.90 | 54.36 | 67.75 | 97.41 | 41.15 |
| **HIC**** | 236 | 79.73 | 96.75 | 52.81 | 81.99 | 96.97 | 58.23 | 77.10 | 96.48 | 47.66 |
| **Product** | | | | | | | | | | |
| Rice | 85 | 71.5 | 56.2 | 85.0 | | | | | | |
| Other Grains | 48 | 71.4 | 49.7 | 94.1 | | | | | | |
| Other Crops | 119 | 74.6 | 47.4 | 90.7 | | | | | | |
| Whole Farm | 37 | 77.0 | 59.3 | 84.6 | | | | | | |
| Dairy | 168 | 81.3 | 56.0 | 96.8 | | | | | | |
| Other Animals | 27 | 84.4 | 51.0 | 99.1 | | | | | | |

*Source:* Bravo-Ureta, Rivas, and Thiam (2001).
*LIC: Africa, Latin America and Caribbean, Asia (w/o Malaysia), Ukraine.
**HIC: Western Europe, North America, Malaysia, Slovenia.
ND: No Data.

Table 6 summarises technical efficiency estimates reported in seven studies that used farm, level data for Pakistan. These seven studies yield a total of 22 average technical efficiency measures, where five are deterministic parametric, two non-parametric, and the remaining 15 are stochastic. The single most studied crop has been wheat (seven estimates), followed by cotton, sugarcane, and maize (two estimates for each). The efficiency studies have been performed for various regions of the country, but the North West Frontier Province (NWFP) has received most attention.

The mean TE estimates presented in Table 6 range from a low of 57 percent for wheat production in Badin to a high of 88.0 percent for cocoons in Changa-Manga and Chichawatni. The average TE for the deterministic frontiers is 70.1 percent and 77.0 percent for the parametric and the non-parametric models, respectively. The stochastic frontiers yield an average of 76.7 percent for cross-sectional data and 68.0 percent for panel data. The overall average for all 22 cases is 72.9 percent, which is somewhat lower than the 76.7 percent overall average reported by Bravo-Ureta, Rivas, and Thiam (2001) for the 484 cases they analysed (see Table 4). In summary, the data for Pakistan reveal that overall output could be increased, on average, by about 27 percent if the farms included in the studies were to operate on their respective frontiers.

Table 6

*Technical Efficiency (TE) Estimates for Pakistani Farms*

| Author(s) and Year of Publication | Region/ Province | Product | Functional Form[1] | Sample Size | TE % |
|---|---|---|---|---|---|
| **I. Deterministic Production Frontiers** | | | | | |
| ***(a) Parametric Frontiers*** | | | | | |
| Ali and Chaudhry (1990) | Punjab | Crops | CD | 220 | 84.0 |
| Shah, Ali, and Khan (1994) | NWFP | Wheat | CD | 382 | 72.2 |
| | NWFP | Maize | CD | 378 | 59.6 |
| | NWFP | Sugarcane | CD | 376 | 65.3 |
| | NWFP | Crops | CD | 383 | 69.3 |
| *Average* | | | | | *70.1* |
| ***(b) Non-parametric Frontiers*** | | | | | |
| Shafiq and Rehman (2000) | Punjab | Cotton | N.A. | 117 | 67.2 |
| | Punjab | Cotton | N.A. | 117 | 86.7 |
| ***Average*** | | | | | ***77.0*** |
| **II. Stochastic Production Frontiers** | | | | | |
| ***(a) Cross-sectional Frontiers*** | | | | | |
| Bashir, Muhammad, and Khan (1995) | D. I. Khan | Wheat | RTL | 150 | 67.0 |
| Ahmad and Qureshi (1999) | Rawalpindi | Agg. Output | CD | 117 | 62.0 |
| | Gujranwala | Agg. Output | CD | 125 | 82.0 |
| | Faisalabad | Agg. Output | CD | 261 | 81.0 |
| | Multan | Agg. Output | CD | 556 | 68.0 |
| | Thal | Agg. Output | CD | 170 | 79.0 |
| Ahmad and Shami (1999) | Changa-Manga and Chichawatni | Cocoons | CD | 80 | 88.0 |
| Shah, Ali, and Khan (1994) | NWFP | Wheat | CD | 382 | 87.1 |
| | NWFP | Maize | CD | 378 | 76.1 |
| | NWFP | Sugarcane | CD | 376 | 71.0 |
| | NWFP | Others | CD | 383 | 82.6 |
| *Average* | | | | | *76.7* |
| ***(b) Panel Data*** | | | | | |
| Battese, Malik, and Gill (1996) | Faisalabad | Wheat | CD | 109 | 78.9 |
| | Attock | Wheat | CD | 138 | 58.4 |
| | Badin | Wheat | CD | 113 | 57.0 |
| | Dir | Wheat | CD | 139 | 77.5 |
| *Average* | | | | | *68.0* |
| *Overall Average* | | | | | *72.9* |

[1] CD=Cobb-Douglas. RTL= Restricted Translog.

N.A.= Not Applicable.

## 6. CONCLUDING REMARKS

Several conclusions can be drawn from the preceding discussion. First, despite the seeming inevitability of the "economic transformation", it is reasonable to state that agriculture will continue to play a crucial role in the economy of most developing countries, and certainly in Pakistan. Agriculture will not only provide food, employment, internal demand for other domestic products, and foreign exchange, but it must also play a critical function in the alleviation of poverty in low-income countries. Poverty alleviation is not only a national problem: in a shrinking world it has become an international priority and a moral imperative, as evidenced by IFPRI's 2020 Vision and other initiatives.

Second, the large amount of empirical evidence accumulated in the literature clearly suggests that investing in the generation (research), dissemination (extension), and adoption (education and support services) of new agricultural technologies has a high social rate of return. At the same time, given the public-goods nature of agricultural knowledge, public sector involvement in the generation and provision of this knowledge is warranted particularly in poor countries [Stiglitz (1987)]. To achieve the full potential of gains in productivity needed in developing countries, it is imperative for the public sector not only to design and implement a research strategy that would generate technologies that are usable and appealing to farmers but also to provide an environment conducive to the private sector's active involvement in this effort. According to Ahmad and Nagy (2001), Pakistan made significant progress in encouraging overall private investment between 1982 and 1997. In agricultural research specifically, private investment more than doubled in the 1987–97 period. These authors argue that despite this progress, improvements in the financial, political, and economic stability of the country would further promote private investment.

The third point is that the empirical evidence for many countries, including Pakistan, indicates that there is considerable room to increase agricultural output without additional conventional inputs and without requiring the introduction of new technologies. These efficiency gains would raise output and farm profits, as well as improve competitiveness. Consequently, there is a clear rationale for supporting producers so that they can achieve higher efficiency from the technology already available to them. At the same time, it is necessary to have suitable mechanisms in place that facilitate the dissemination of new technologies, from research plots to farmers' fields, so that the efficient use of new practices can be accomplished in a short time-period. These mechanisms include well-articulated extension services, credit availability, input supplies (particularly high quality seeds), output marketing, and market information, among other factors. This challenge will become even more significant as the emerging biotechnological revolution takes hold.

The timely adoption of new technologies is important because it leads to reductions in per unit cost of production and to improved short-run profitability for those who are early innovators [Hazell and Haddad (2001)]. Empirical evidence indicates that in regions or countries that have not benefited from agricultural productivity growth, farmers have lost competitive advantage. Moreover, from a national perspective, agricultural productivity growth contributes to the reduction in food prices, which in poor countries means an increase in the purchasing power of wages, thus lowering the cost of industrial development [Ruttan (2002)].

Before closing, it is important to emphasise that although we have many studies that document the gap in technical efficiency, we have a considerable way to go towards understanding the determinants of efficiency and factors that can stimulate higher levels of performance at the farm level in a cost-effective fashion. Two crucial elements are (i) to boost entrepreneurial ability and (ii) to improve the quality and quantity of information available to producers, particularly to peasant farmers. In this regard, the Farm Management Centre (FMC) model, which has been developed and implemented successfully in some European countries, particularly Spain, France, and Denmark, and that more recently has made some inroads in developing countries like Chile and El Salvador, deserves analysis to determine if it is adaptable to other countries and cultures [Solís (2002)]. The FMC model has been promoted as a private extension service alternative in response to the decline in public support for extension services experienced since the mid-1980s [Dinar (1996)]. It is safe to assume that the pressures to find alternatives to public extension systems will not dissipate any time soon.

The objectives of the FMCs are to increase farm productivity and profits by strengthening entrepreneurial capacity among resource-constrained farmers, promoting and facilitating the adoption of environmentally friendly technologies, and generating and providing timely market and technical information so that decision-making at the farm can be improved. The lack of access to information about markets, technology, and finance remains a major obstacle to improving productivity and competitiveness for subsistence farmers in developing countries. This paucity of information is a barrier to entering the market economy and confines these farmers to remain in poverty. To improve the competitiveness of subsistence farmers within global markets, it is necessary to encourage and facilitate their progressive integration into the market economy. For this integration to take place, it is essential that farmers have access to reliable up-to-date information so that they can improve the profitability of traditional products and evaluate the adoption of higher-value products and technologies that are compatible with environmental quality.

A final point is that in order for professional economists, particularly those of us who do applied work, to advance our understanding of the drivers of productivity growth at the farm level, it is necessary to improve data quality and availability. This author's experience is that considerable effort is devoted in expensive farm data collection exercises, but there is no coordination or systematic approach behind this work. Consequently, data collection efforts, which could and should generate the raw material we need to perform meaningful economic studies and thus contribute to policy design, are largely lost efforts. My hypothesis is that with a reasonable level of effort, this situation could be vastly improved. To quote Richard Just, "…agricultural economics research is in some important ways, off track…..[and]…data availability is perhaps the greatest constraint" (2000, p. 155).

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# Comments

## *1.*

At the outset, I would like to compliment Professor Bravo-Ureta for his excellent paper, extensive survey of the literature on agricultural development, and equally impressive presentation of his arguments on the subject. The subject of the paper is important not only for the development of agriculture but also in understanding the process of development itself, which is so important to alleviating poverty, the bane of developing countries. I hope those holding the purse strings and concerned with providing resources for development of agriculture, as well as the ones managing the resources in agricultural research and extension, would also be favourably impressed by the analysis and arguments of the learned author. I cannot agree more with him on the crucial role of agriculture in the overall development and the need for raising productivity in farming in this context in the developing countries which are dependent on agriculture. However, this requires a lot of painstaking and concerted effort, working with the farming population and a favourable economic environment for promoting investment in agriculture.

In the second section of the paper, after highlighting the contribution of agriculture to the development process and an extensive survey of the literature, the author notes the declines experienced in its share in GDP, employment, exports, etc., as the per capita income increases as a sequel to the economic transformation and development of the economy. In view of its importance, a case for suitable policy environment to further the development of agriculture sector is pleaded. Drawing on the evidence and arguments of famous development economists, the author has forcefully refuted the negative views about the importance of agricultural development and underscored its role in meeting the increasing food needs of increasing numbers of population, and in providing foreign exchange and capital for overall development. He has also emphasised the need for increasing productivity in farming as farm resources face increasing challenges and competition from other sectors of the economy. Building on the seminal work of T. W. Schultz, the "poor but efficient hypothesis", the author argues that gains in productivity in traditional agricultural setting are only possible through technological change based on research, and on the education of farmers to benefit from new technologies. He has also revisited John Mellor who emphasises the inter-dependence between agriculture and industry, and the linkages between these sectors. Technological change and improvement of efficiency in raising agricultural productivity are rightly argued to be the major sources of growth and priority areas for providing technical and economic assistance for the low-income countries.

However, in this context, I would like to add that a favourable pricing policy environment conducive to farm investment can facilitate the adoption of technological innovations. An economic environment which does not reward the farmers for increasing productivity and leads to low producer prices for the increased farm production can hold back the progress for sustainable development in the sector.

In view of its prominent contribution to GDP, exports, and provision of employment and raw material to the industry, agriculture holds the key to economic development in Pakistan. However, in the wake of increasing input prices, deteriorating terms of trade, and adverse weather conditions, agriculture has experienced an erratic growth rate in recent years, adversely affecting the economic development and poverty alleviation in the country.

Historically, agriculture has contributed material resources as well as labour for the development and capital formation in other sectors. But given the high incidence of rural poverty, should agriculture continue to be subjected to resource transfers via deteriorating terms of trade and implicit taxation? This needs review and dispassionate analysis.

The author argues that agricultural research has been supported by government funding as a public good and such investments have yielded high rates of return. The author has also marshalled impressive evidence, from all over the world, to support his claim of significant returns to investments in agricultural research and extension. However, there is a wide range in the rates of returns, both across various countries, and across commodities within a given country/region. As reported by the author, rate of return to investment in research ranges from 17 percent on fruit trees in North America to 340 percent for animal products in Asia. For extension, the lowest rate of return, 23 percent, is in Latin America, while the highest, 144 percent, is in North America. The studies combining the returns to investment in research and extension have indicated the range of 9 to 133 percent. The overall average rates of returns have been from 62 to 102 percent for research, from 40 to 54 percent for extension, and from 43 to 66 percent for research and extension when combined.

Understanding the factors responsible for these wide variations in the rates of return to investments in agricultural research and extension holds the key to agricultural development. I wish Professor Bravo-Ureta had spent some time on explaining the factors underlying this variation to advance our understanding of the subject, which is crucial for the cause of food security and poverty alleviation in the developing countries.

The studies on Pakistan as reported by Professor Bravo-Ureta indicate a range of 17–102 percent in the rates of return to investments in research and extension. For research and extension combined, the lowest rate of return is of 19 percent, while the highest reported in 65 percent. Average rates of all studies focusing on research range from 52 percent to 67 percent. The important question which arises in this context is why the average rates of return to investments in agricultural research in Pakistan (in comparison to other countries) have been lower? Does it have to do with the following:

- overall policy environment;
- output prices and structure of commodity markets;
- problems of grassroots support to agriculture;
- quality and availability of modern inputs;
- shortage of a minimum mass of trained manpower; (Do we provide for such a critical level for research and is the environment conducive to the retention of trained manpower?)
- level of technical, financial, and infrastructure support to researchers; and
- continuity of the programme and leadership in the research organisations?

I believe that Pakistani farmers as well as researchers are second to none. Nevertheless, they have not enjoyed a level playing field. Maybe this has to do with relatively low rates of return to investment in research and extension in Pakistan.

It is an open secret that scientists working in public sector agricultural research institutions faced with dwindling resource suffer from a low morale and are on the look-out for greener pastures elsewhere. Increasing investment in agricultural research is a necessary condition for technological developments and high returns to investments in this context, but sufficient conditions also need to be identified and analysed. I am afraid these are bound to be location- and country-specific. In the context of the changing world scenario and globalisation, it has become all the more important for the developing countries to develop an indigenous capacity to address the technical issues and to evaluate the impact of various developments on their agriculture.

**Technical Efficiency**

Reviewing the literature on technical efficiency in agriculture, the author has pointed out that technical efficiency of agriculture in rich countries is comparatively higher: 80 percent in comparison to 74 percent of low-income countries. At the same time, rich countries are subsidising their agriculture in one or the other form, to the tune of $ 360 billion per year; while many of the low-income countries, either for lack of resources or under pressure from donors, are unable to do so. Under these circumstances, globalisation, which is supposed to provide the means of higher growth, may not be of much help for the agriculture of the developing world.

It would be in the fitness of things for the international community to heed Anderson's (2002) advice, as quoted by Professor Bravo-Ureta in his paper, and provide greater technical assistance to agriculture research, rural education, health, and rural infrastructure in the developing countries as a co-requisite of reforms in trade policy in the wake of the Doha Declaration.

Although liberalisation tends to enhance economic growth, it could have unfavourable effects on peasant farmers especially when developed countries continue to subsidise their agriculture. As Bathrick (1998) has observed: after years of structural biases and general disinterest in the developing world's agriculture, global trade is now forcing poorer, agrarian-based economies to assess their natural comparative advantage and quickly adapt. Revolutionary structures, policies, and strategies are now required to meet the new challenges. The changes under way offer considerable opportunities. However, the majority of small and medium producers (farmers) and rural non-farm families are ill-equipped to either gain from the broader benefits or respond to previously unknown competitors, as they lack the relevant experience, skills, and financial support to adjust to the new conditions/realities. Thus, distant and not necessarily more efficient (but perhaps better-supported and subsidised) producers have now more chances to penetrate new markets or expand their market shares in the old ones.

Increasing agricultural productivity—and improving the efficiency of resource use (through technical change and efficiency improvements) must be a major priority. It is imperative to provide for both the hardware, i.e., technological innovations, and the software parts i.e., upgradation of the farmers' skills and the know-how about the technological innovations and complementary management skills. Based on a review of various studies in Pakistan, Professor Bravo-Ureta has concluded that overall output could be increased on average by about 27 percent, if the farmers are to operate on their respective productivity frontiers. However, it must be emphasised that it will require objective identification and analysis of the relevant factors constraining their movement towards the productivity frontier.

The results of APCom surveys of various crops also indicate wide gaps in the productivity of major crops across various groups of farms in a given crop zone, and across various regions for a given crop.

Classified on the basis of their management practices, wheat yields of 'progressive' farmers were 52 percent and 123 percent higher as compared to those of the 'average' and 'traditional' farmers. The unit cost of production of progressive wheat farmers was 48 percent less than that of 'traditional', and 26 percent less than that of 'average' farmers, while the unit cost of 'average' farmers was 29 percent less than that of 'traditional' farmers [Salam, *et al.* (2002)].

It is rather difficult to single out any one factor in this context. The need for improving technical know-how, availability and use of modern inputs, timing, mix and method of their use, and complementary practices are all important to increasing farm productivity. At the same time, assuring adequate arrangements for the marketing of the produce and reasonable producer prices, at harvest time, providing a safe margin over the cost of production, are also crucial. The lack of markets and low producer prices in years of good crop can send negative signals and hamper the cause of sustainable agricultural development via increase in farm productivity.

**Data**

Professor Bravo-Ureta has highlighted the need for improving the quality of data and its availability to advance our understanding of the drivers of productivity growth at farm level. I share his concern about improving the quality of micro data on various aspects of farm production and marketing. It is important to regularly organise well-designed farm surveys to capture the changes and developments in farm sector at the grassroots level. In the wake of globalisation, agriculture will face tremendous challenges as well as opportunities, which would need to be monitored and analysed for suitable policy adjustments.

It should be appreciated that field surveys are not only demanding in terms of manpower and material resources but also require professional supervision and leadership to ensure the quality and integrity of data. There are formidable problems in improving the quality of data as farmers generally rely on their memory while providing information for various surveys. Farm records, even if maintained, are seldom available to the researchers. At the same time, farmers apprehend that the information provided by them may be used for tax and other such purposes to their disadvantage. To compound the problems, the researchers are faced with financial constraints and many other demands on their time. The problems are not necessarily insurmountable but require due consideration, understanding, and attention of those concerned with providing the resources and decision-making.

In conclusion, I would like to thank Pakistan Society of Development Economists for inviting me to participate in the Annual Meeting, and for the opportunity to discuss a highly interesting paper.

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## *2.*

It is a privilege to be a discussant on this distinguished paper by an eminent economist. I appreciate Professor Bravo-Ureta's keen interest in Pakistan's agriculture. The author has rightly emphasised the role that the agriculture sector can play in the economic development of less developed countries (LDCs) like Pakistan. The extensive review of the literature on the measurement of technical efficiency and methods to estimate the rates of return to investment in agriculture research and extension is the real strength of the paper.

The study presents empirical evidence from the literature that investment in agricultural research has resulted mostly in attractive rates of return in Pakistan and elsewhere in the world. I have the feeling that these rates are only indicative and largely depend on the set of assumptions and methodologies involved. The high rates should not be fascinating us so much as, to jump to the conclusion that we should invest more in agricultural research, if the externalities resulting from the adoption of new technologies are ignored while estimating these rates. I fear that the present state of the art does neglect the externalities like degradation of land and water resources, loss of bio-diversity, environmental pollution, and damage to human and animal health, etc. These externalities may be quite sizeable in some societies; ignoring them would result in an overestimation of the rates of return on investment in agriculture research and would make these rates look respectable.

Similarly, the low returns do not necessarily mean that we should stop investing in agricultural research, as they might be low because of the prevalence of inefficiencies in the research system or the same conditions at the farm level. A better alternative would be to improve the efficiency of the inefficient system; for example, inefficiencies arising from duplication of research efforts, employment of support staff, low salaries, promotion criteria strictly based on seniority, etc.

I agree with the author that improving efficiency of the inefficient farms can lead to a substantial increase in agricultural output in Pakistan without using additional conventional inputs and the introduction of new technology. However, supportive services and the marketing system have failed in Pakistan in providing the small and marginal farmers an easy access to credit, extension services, just prices, and quality inputs.

The methods for measuring the farm efficiencies seem to be restrictive in the sense that they require that all the farms face the same set of inputs, technology, prices, quality of inputs, and quality of land and water resources. In reality, most of them differ from farm to farm in Pakistan, and I wonder if the methodology would work in this case. For example, farmers with saline land resources may be ranked as inefficient when compared to farmers having normal or fertile farmland in the same sample. Whereas in reality the same farmer may prove to be the most efficient one when provided with fertile land. Or he may be getting the highest possible output and be the most efficient when studied in the domain of farms having similar land resources. Similarly, farmers in Pakistan also face diversified input quality and different sets of input-output prices. Certain farmers may reflect the same level of efficiency with respect to resource allocation, but the farmers who ended up using a low quality input because of the problem of adulteration and, as a result, had low production would be ranked inefficient. A farmer facing an adverse set of prices may be ranked inefficient when studied together with a farmer given a favourable set of prices who may be producing efficiently only account of the given set of prices governing his productivity.

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