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# Total Factor Productivity Growth in Pakistan's Agriculture: 1960–1996

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## 1. INTRODUCTION

Nearly one-quarter of Pakistan's Gross Domestic Product (GDP) is contributed by the agriculture sector and it employs nearly 44 percent of the labour force. Agricultural exports, directly and indirectly, make up a large proportion of total exports and foreign exchange earnings of the country. Agriculture in Pakistan faces considerable challenge in the 21st century. The present population of about 149 million, growing at about 1ta. 9 percent per year, is expected to double to 298 million in about 40 years. Pakistan's agriculture has experienced rapid growth since the 1960s. The average annual growth of about 4 percent in the four decades before the onset of the new millennium has exceeded the population growth that touched about 3 percent for a substantial part of this period.[1] This rate of growth in agriculture has been sustained by the technological progress embodied in the high-yielding varieties of grains and cotton with supporting public investment in irrigation, agricultural research and extension (R&E), and physical infrastructure. Agricultural growth, in turn, has made significant contribution to the overall economic growth of about 6 percent per year during this period. Despite rising per capita income, food demand is likely to grow rapidly given the low level of current per capita income. There is a compelling need for sustained efforts to increase production of essential items (wheat, edible oils, etc.). Faced with limits to further expansion of cultivated land and slowing returns to further input intensification, productivity growth assumes a central role in meeting the challenges of the future.

The most comprehensive measure of aggregate or sectoral productivity is Total Factor Productivity (TFP). However, given the paucity of good data, this area

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[1]Pakistan's population grew at an average rate of 3 percent per annum till the mid-1980s. Thereafter, it slowed down to an average rate of 2.6 percent per annum during 1985-86 and until 1999-2000.

of research has remained quite limited in Pakistan. There have been only few studies so far and all of them, with the exception of Khan (1997), have used the data on crop production, excluding livestock. In the present study, the TFP change in Pakistan's agriculture sector, including crops and livestock, is estimated for the period 1960-61 to 1995-96 using improved notions of output and inputs measures.[2] Since no official agency in Pakistan maintains a TFP index for the agriculture sector, no effective mechanism exists for monitoring changes in the efficiency of resource use in agriculture on a regular basis and assessing the sustainability of various policy approaches. This study, therefore, would provide a fresh perspective on the growth of TFP in agriculture for use in developing appropriate policy responses towards this sector of Pakistan's economy.

## 2. TFP MEASUREMENT IN PAKISTAN'S AGRICULTURE: A BRIEF SURVEY

There have not been many studies measuring TFP growth in Pakistan agriculture. Wizarat (1981), in a pioneering study of changes in agricultural productivity for the period 1953-54 to1978-79, computed arithmetic TFP index in a growth accounting framework using the linear production function approach. While reflecting the broad contours of productivity change over the sample period, there are serious data and methodological limitations in the study.[3] In addition**,** the study only focuses on the crop sector whereas livestock output also contributes importantly to total agricultural production. Khan (1994), also using an arithmetic index, formulation, estimated TFP growth for the crop subsector during 1980–93. Compared with annual TFP growth of 2.7 percent in Wizarat's study, Khan (1994) estimates annual TFP growth at 1.8 percent (Table 1).

Using the Tornqvist-Theil (T-T) methodology, Rosegrant and Evenson (1993) have estimated the TFP growth for the period 1956-1985 in the crop sector, using disaggregated data covering 35 districts in three provinces. TFP, in their study, grew rapidly in the early Green Revolution at a rate of 1.8 percent per annum but, rather surprisingly, declines very sharply thereafter (Table 2.). Furthermore, TFP growth is found to have accounted for about one-third of total output growth over the period of study.[4] Both Wizarat (1981) and Khan (1994, 1997), on the other hand,

[2]The choice of this period for study is premised on the fact that as a result of policy neglect of agriculture, no significant productivity growth occurred in Pakistan's agriculture before the 1960s.

[3]An arithmetic index, derived from a linear production function, assumes perfect substitutability between inputs. The use of a value-added output index implies the existence of a value-added function, which apart from the separability restrictions excludes the role of intermediate, purchased inputs. In addition, the capital input variable has been constructed as a stock whereas a service flow concept would be the more appropriate.

[4]The determinants of TFP growth are also analysed by decomposing the productivity residual using regression techniques. They find that agricultural research, high yielding varieties (HYVs), literacy, and share of irrigation are the major sources of TFP growth.

Table 1

*TFP Growth in Pakistan's Agriculture,1960–96*

| Year | Agricultural GDP (1980-81 Prices) | Wizarat (1981) | Khan (1994) | Khan (1997) |
|---|---|---|---|---|
| **Average Annual Growth Rate (%)** | | | | |
| 1960–65 | 4.59 | 3.70 | | 1.3 |
| 1966–70 | 7.84 | 9.50 | | 4.5 |
| 1960–70 | 5.19 | 4.70 | | 2.2 |
| 1971–75 | 2.00 | 0.06 | | 0.1 |
| 1976–80 | 3.65 | 1.20 | | 0.0 |
| 1971–80 | 2.62 | 0.57 | | –0.1 |
| 1981–85 | 2.85 | | 0.66 | 0.7 |
| 1985–90 | 4.12 | | 1.19 | 0.6 |
| 1981–90 | 4.12 | | 1.56 | 0.8 |
| 1991–93 | | | 3.97 | |
| 1991–96 | 3.69 | | | |
| **Total Period** | | | | |
| 1960–79 | 3.71 | 2.74 | | |
| 1981–93 | | | 1.87 | |
| 1960–96 | 3.75 | | | 0.8 |

*Note:* Wizarat (1981) and Khan (1994) use arithmetic index; Khan (1997) uses T-T index.

Table 2

*Annual Rates of Growth of TFP in Crops , 1956–85*

| | 1956–85 | 1956–65 | 1965–75 | 1975–85 |
|---|---|---|---|---|
| Pakistan | 1.07 | 1.65 | 1.86 | –0.36 |
| Pakistan Punjab | 1.06 | 1.42 | 2.13 | –0.84 |

*Source:* Rosegrant and Evenson (1993). Period (1965–75).

find TFP growth in the post-1975 period to have been positive and improving after a period of stagnation in the first half of the 1970s (Table 1). One reason for the conflicting results may lie in the unreliable data-set used by Rosegrant and Evenson [Khan (1997), p. 311]. The study carries no explanation for the panel data set covering 35 districts and 30 year period (1955–85) since the official documents do not report the data at this level of disaggregation for many of the variables (inputs) used in the analysis.

## 3. METHODOLOGICAL FRAMEWORK AND DATA

### Methodological Framework

To measure total factor productivity the most frequently applied techniques in literature on agriculture are: (a) Arithmetic Index (AI); and (b) Tornqvist-Theil Index

(TTI). The arithmetic index technique is the simplest measure of TFP for the agriculture sector, which is defined as a ratio of the total output index to input index. The input index is constructed as a linear aggregation of inputs with input shares in total input cost as weights. The index can be easily derived assuming a linear homogenous production function and competitive labour markets. Despite its theoretical limitations, it is the easiest to calculate. Following Wen (1993), the simplest version of a TFP Index can be algebraically written as:

$$TFPI_t = \frac{100 \times (GVAO\ Index)_t}{\alpha(\ Lan\ Index)_t + \beta(K\ Index)_t + \delta(Lab\ Index)_t + \phi(M\ Index)_t} \quad \ldots \quad (1)$$

where the output index in the numerator is based on the Gross Value of Agricultural Output (GVAO). The input index in the denominator is a linear aggregation of cultivated land (*Lan*), capital (*K*), labour (*Lab*), and material inputs (*M*), using $\alpha, \beta, \delta, \textit{and}\ \phi$ (the respective share of each factor input in total input cost in the base year) as weights. The main shortcoming of this indexing procedure is the fixed nature of the weights used in aggregation, which makes the index sensitive to the choice of factor shares.

The second method is the the Tornqvist-Theil (T-T) approximation to the Divisia index, which is most widely being used to measure TFP in agriculture. Following Chambers (1988), Capalbo and Antle (1988), and Thirtle and Bottomley (1992), the TTI formulation can be written as

$$\begin{aligned} \ln(TFP_t / TFP_{t-1}) &= 1/2\sum_i (R_{it} + R_{it-1}) \ln(Y_{it} / Y_{it-1}) \\ &\quad - 1/2\sum_j (S_{jt} + S_{jt-1}) \ln(X_{jt} / X_{jt-1}) \quad \ldots \quad \ldots \quad \ldots (2) \end{aligned}$$

where $R_{it}$ is the share of output $i$ in total revenue, $Y_{it}$ is output $i$, $S_{jt}$ is the share of input $j$ in total input cost, and $X_{jt}$ is input $j$, all in period $t$. In this specification, revenue shares for the output index and cost shares for the input index are updated every time period as compared with the use of fixed weights in the arithmetic and geometric indices, thus avoiding the underestimation/overestimation implicit in a fixed-weight estimation procedure.

**The Data**

In this study, the TFP index for the period 1960-96 is computed with a gross output index that includes both crops and livestock products and the aggregate input index that also includes purchased inputs (fertilisers and pesticides). In agricultural productivity analysis, a decision has to be made at the outset whether to use the gross or net output (value-added) measure of productivity. The gross output series includes all of the final agricultural output of a sector; on the other hand, the value-added series measures the output produced by the inputs originating within the sector, i.e.

the intermediate inputs are excluded. Some of the existing studies in Pakistan [Wizarat (1981); Khan (1994, 1997)] have used an output index based on value-added data—gross value-added (GVA) in million Rupees—while others have used a gross output index [Rosegrant and Evenson (1993)].[5] In the Green revolution context of Pakistan, where technological change in agriculture came about with the introduction of HYVs and the associated use of complementary chemical inputs, the use of gross output index is more appropriate.[6]

The input index is constructed with land, labour, tractors, tubewells, work animals, and purchased inputs (fertiliser and pesticides). As far as is possible, an effort has been made to measure input as flow variables. A detailed discussion of the conceptual and practical issues relating to the data used in the study is given in the appendix.

## 4. RESULTS AND INTERPRETATION

Total Factor Productivity in this study has been estimated using both arithmetic and Tornqvist-Theil indexing methodologies. The estimated annual growth rates of agricultural GDP and the TFP using arithmetic index procedure based on 1960-61 and 1980-81 weights are given in Table 3. The highest growth rate of TFP is observed in the early Green Revolution period (1965–70) and the lowest is found during 1971–1975 period. For other periods, the estimated index calculated using 1960-61 shares performs relatively better as the sub-period growth rates as well as the TFP growth rate for the entire period appear to be more reasonable.

The results given in Table 3 clearly show that the TFP growth measures using arithmetic indexing procedure are not independent of the choice of factor shares.[7] The reasons behind this result are that applying the 1980-81 factor shares to the

[5]The gross value added (GVA) reported in official documents is obtained after subtracting intermediate purchased inputs from total gross value of output. On theoretical grounds, however, a value added series may not be an appropriate data series to work with because it implies existence of a value-added function, which in turn depends on the highly restrictive and unrealistic assumption of separability of intermediate inputs from primary inputs. Furthermore, even if the existence of the value-added function is presumed, the results obtained may be inaccurate and biased. The exclusion of intermediate inputs (seeds, fertilisers, pesticides etc.) would tend to attribute measured technical progress to capital and labour input, not leaving any room for enhanced efficiency in the use of purchased inputs.

[6]For use in the arithmetic index, the data series for gross value of output based on 1980-81 prices was obtained from the *Report of the Sub-Committee on Sources of Growth*, Committee on Economic and Social Well-Being for the Eighth Five Year Plan, May 1992 [Kemal and Islam (1992)]. As this latter data series only extended up-to 1992, it was brought up to the year 1996, with gross output data for major crops, minor crops and livestock reported in the Agricultural Statistics of Pakistan (ASP).

[7]The factor input shares in total input cost for 1960-61 and 1980-81 are:

| | 1960-61 Weights | 1980-81 Weights |
|---|---|---|
| Land | 0.382 | 0.305 |
| Labour | 0.577 | 0.596 |
| Farm Capital | 0.035 | 0.054 |
| Current Inputs | 0.004 | 0.044 |

Table 3

*TFP Changes with Arithmetic Index, 1960–96*

| Year | GVAO | TFP 1960-61 Weights | TFP 1980-81 Weights |
|---|---|---|---|
| **Annual Average Growth Rates (%)** | | | |
| 1960–65 | 4.90 | 2.97 | 2.67 |
| 1966–70 | 7.12 | 6.26 | 3.49 |
| 1960–70 | 5.18 | 3.99 | 2.78 |
| 1971–75 | 2.24 | 0.93 | –0.59 |
| 1976–80 | 4.31 | 1.97 | –0.30 |
| 1971–80 | 3.11 | 1.07 | –1.20 |
| 1981–85 | 3.15 | 2.00 | 0.61 |
| 1985–90 | 3.92 | 2.05 | 1.69 |
| 1981–90 | 4.32 | 2.43 | 0.63 |
| 1991–96 | 3.72 | 1.62 | 0.50 |
| Total Period (1960–96) | 3.85 | 2.17 | 0.40 |

*Note:* GVAO is gross value of agricultural output at 1980-81 prices [Kemal and Islam (1992)].

earlier period overstates the contribution of labour, farm capital, and current inputs and understates the role of land, thus depressing the TFP growth in the early part of the sample period. Given the dependence of results for the arithmetic index on which weights are used, a Divisia index is considered to be the appropriate method in this case.

In order to overcome limitations of arithmetic aggregation methodology, the Tornqvist-Theil indexing procedure has been used in this study. The estimated indices of output, input, and TFP are shown in Annex 2. The TFP growth rates using these indices are provided in Table 4. These growth rates clearly show a strong performance in the second half of the1960s. This corresponds with the beginning of the Green Revolution as the high yielding varieties of rice and wheat were introduced in Pakistan during this period. Growth in productivity tapered off in the first half of the 1970s, and the factors behind this dismal performance have been the politically-induced institutional experiments, drought conditions in 1970-72, and the heavy rains and accompanying floods in 1973-74, amongst others. There was a slow and gradual recovery in productivity growth in the late 1970s and the early 1980s, with the exception of a brief downturn in 1983-84 largely due to adverse weather. Thereafter, an annual TFP growth rate of 2.4 percent has been sustained, barring a dip in 1992-93 due to adverse weather and large-scale pest attack on cotton. While the productivity gains in the 1980s and 1990s were much lower than the impressive growth experienced in the early Green Revolution years (1965-70), they still reflect a fairly robust performance by agriculture. Figure 1 in the data annex provides a visual representation of these trends.

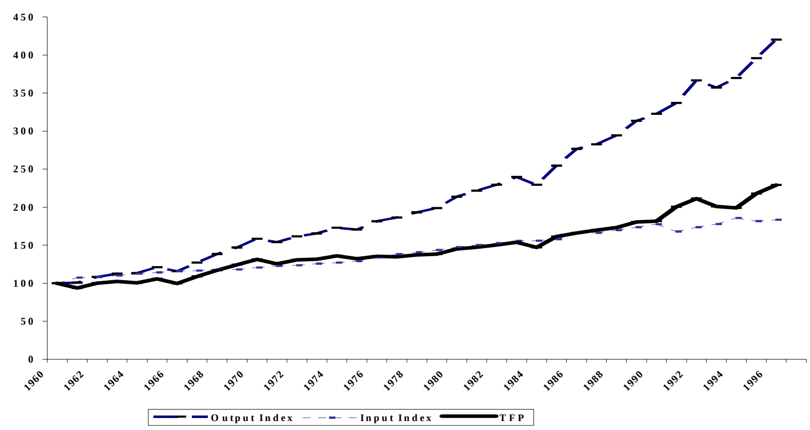
Table 4

*Annual Average Growth Rates (%) of Agricultural GDP, Output, Input, and TFP (Tornqvist-Theil),1960–96*

| Year | Agricultural GDP (1980-81 Prices) Index | Output Index | Input Index | TFP Index |
|---|---|---|---|---|
| 1960–65 | 4.0 | 3.9 | 2.4 | 1.5 (38) |
| 1966–70 | 7.8 | 8.0 | 0.9 | 7.0 (87) |
| 1960–70 | 4.9 | 4.5 | 1.6 | 2.8 (62) |
| 1971–75 | 2.0 | 2.8 | 1.3 | 1.5 (53) |
| 1976–80 | 3.6 | 4.0 | 2.4 | 1.6 (40) |
| 1971–80 | 2.6 | 3.4 | 2.2 | 1.2 (35) |
| 1981–85 | 2.8 | 2.8 | 1.2 | 1.6 (57) |
| 1985–90 | 4.1 | 4.2 | 1.7 | 2.4 (57) |
| 1981–90 | 4.1 | 4.5 | 1.9 | 2.6 (58) |
| 1991–96 | 3.7[8] | 4.0 | 1.8 | 2.2 (55) |
| Total Period (1960–1996) | 3.7 | 4.0 | 1.7 | 2.3 (58)[9] |

*Note:* The numbers in parentheses in the last column are the percent contribution of productivity growth to output growth.

**Fig. 1. Output, Input and TFP Indices, 1960–1996.**




[8]The annual average rate of growth of agricultural GDP for this period includes the abnormally high growth of 11.7 percent in agricultural GDP recorded in FY1996. Subsequent research has shown this to be a statistical artifact mainly due to the abnormally high growth of livestock value-added reported for that year [Malik (2005)]. This very large reported growth is attributable to the livestock census conducted in FY1996. The large one-time increase in the survey year shows up as the reported growth rate of livestock value-added of 26 percent. Instead of a one-time increase in livestock value-added to the extent of 26 percent over the previous year, it would have been appropriate to make a backwards adjustment in the under-reported numbers for value-added over several years. This adjustment reduces the overall agricultural growth rate for the FY 96 to 4.7 percent from 11.7 percent.

[9]This estimate of the TFP growth does not adjust for any possible impact of the over reported growth in livestock value-added in the FY1996.

The results show that the TFP has grown at an average annual rate of 2.3 percent for the entire period (1960-61 to 1995-96). It accounts for about 58 percent of the total output growth in the country during this period. It is fair to say that productivity growth was a significant driving force in the performance of the agriculture sector in Pakistan for over 36 years.

According to Byerlee (1994) "over the long-run, evidence from a number of countries suggests that an overall rate of agricultural productivity growth of 1.5-2.0 percent can be expected (as measured by the TFP index)"(p.10). This *a priori* expectation is reasonably met by the estimated TFP growth rate of 2.3 percent per year during the entire period in this study. This estimate also falls within the general range of TFP growth rates estimated in studies for other developing economies (see Table 5).

Table 5

*Estimates of Total Factor Productivity Growth in Developing Economies*

| Study | Country/Period of Study | Estimation Methodology and Nature of Data | Average Annual TFP Growth Rate |
|---|---|---|---|
| Hayami and Ruttan (1979) (These results are for the TFP index calculated with total output instead of value added.) | Japan 1876-1969<br>Korea 1920-1969<br>Taiwan 1913-1970<br>Philippines 1950-1969 | Arithmetic index/annual time series | 0.8%<br>0.52%<br>0.7%<br>0.7% |
| Wizarat (1981) | Pakistan (1953-1979) | Arithmetic index/annual time series | 1.1% |
| Wong (1989) | India<br>China (1964-83) | Geometric Productivity index/annual time series | China : –3.86%<br>India : –1.63 % |
| Rosegrant and Evenson (1993) | Pakistan<br>India (1956-1985) | T-T index. Cross-section districtwise/annual time series | Pakistan:1.07%<br>India: 1.01% |
| Thirtle, *et al.* (1993) | Zimbabwe<br>Commercial Sector (1970-90)<br>Communal Sector (1975–90) | T-T index/annual time series | Commercial Sector: 3.43%<br>Communal Sector: 4.64% |
| Khan (1994) | Pakistan (1980-1993) | Arithmetic index/annual time series | 2.1 % |
| Khan (1997) | Pakistan (1960-1996) | T-T index/annual time series | 0.92% |
| Fernandez-Cornejo and Richard Schumway (1997) | Mexico (1940-1990) | T-T index/annual time series | 2.5 % |
| Evenson, Pray, and Rosegrant (1999) | India 1956-1987 | T-T index/Cross-section districtwise/annual time series | 1.3% |

Needless to say that aggregate trends reflect the processes at play at the more disaggregated level. Yield growth for wheat and rice, after a peak performance in the early Green Revolution years, slowed after the mid-1970s (see Annex 3 and 4). On the other hand cotton, which contributed about 20 percent to the value-added of major crops in 1980-81 and 30 percent in 1985-86, has done remarkably well in the same period, touching its highest yield growth of over 5 percent per annum in the post-1985 period. Sugarcane, which makes up about 13 percent of the value-added of major crops, also began to experience improvement in its yield level in the post 1985 period, after a long period of stagnation. Above all, performance of the livestock sector, which constitutes about 30 percent of the agricultural GDP, has been improving since the early1980s, growing at an annual rate of 5 percent since 1985 (see Table 6). Against this background, it can be argued that the remarkably sustained productivity performance of agriculture in the post 1985 period, apart from the likely beneficial impact of the structural adjustment policies on agriculture, is a result of gains in the productivity of cotton and livestock more than offsetting the apparent productivity slowdown in wheat and rice crops.[10]

Despite the considerable short-term stress of structural adjustment and reform policies of the 1980s and the early 1990s, agriculture in Pakistan appears to have demonstrated remarkable resilience in the 1990s: the agricultural value-added has grown at an average annual growth rate of over 4 percent (see Table 7). Agricultural inputs supply has grown steadily (Annex 3) and the terms of trade for agriculture have a clear upward trend (Annex 5).

Farm profitability appears to have improved due to favourable prices for the main crops throughout the 1990s. This improvement in incentives is also reflected in the purchasing power of crops in terms of N and P fertilisers (Annex 6). Adjustments in the nominal and real exchange rates and reform of trade policy have resulted in gradually falling discrimination against agriculture (see Table 7). Despite falling share of allocation to agriculture in ADP, the improving incentive regime for the farmer has been a significant factor in the sustained productivity response of agriculture during the 1990s.

## 5. CONCLUSION AND POLICY IMPLICATIONS

Pakistan's agriculture has experienced rapid growth since the 1960s with an average annual growth rate of about 4 percent over the last four decades (before the onset of the new century) exceeding the population growth rate that remained close to 3 percent for a substantial part of this period. The major source behind this performance has been the growth in TFP, i.e. 2.3 percent, accounting for about 58

[10]A number of studies have sounded alarm about productivity stagnation in Pakistan's crop sub-sector in the post-Green Revolution period [Rosegrant and Evenson (1993); World Bank (1994)]. The results of this study, however, offer no basis for an alarmist scenario as the performance of agriculture—crops and livestock—has been fairly robust since the mid-1980s.

Table 6

Table 7

*Macroeconomic Indicators and Performance of the Agriculture Sector, 1990-91 to 1997-98*

| | GDP ( %) | Agric. Value Added (%) | Budget Deficit (%) of GDP (Market Prices) | Public Expenditure in Agriculture (ADP) Million Rupees | Real Effective Exchange Rate Index (1990=100) | Nominal Effective Exchange Rate Index (1990=100) |
|---|---|---|---|---|---|---|
| 1985-86 | 6.4 | 5.9 | 8.1 | 4435 | 146.88 | 143.75 |
| 1986-87 | 5.8 | 3.2 | 8.2 | 3221 | 124.71 | 120.54 |
| 1987-88 | 6.4 | 2.7 | 8.5 | 3493 | 112.02 | 109.17 |
| 1988-89 | 4.8 | 6.9 | 7.4 | 3990 | 112.59 | 108.17 |
| 1989-90 | 4.6 | 3.0 | 6.6 | 3012 | 103.13 | 103.45 |
| 1990-91 | 5.6 | 5.0 | 8.7 | 3042 | 97.55 | 95.34 |
| 1991-92 | 7.7 | 9.5 | 7.4 | 3692 | 94.42 | 89.98 |
| 1992-93 | 2.2 | –5.3 | 8.0 | 3461 | 99.07 | 91.15 |
| 1993-94 | 4.5 | 5.2 | 5.9 | 2164 | 93.58 | 83.50 |
| 1994-95 | 5.2 | 6.6 | 5.6 | 2004 | 94.65 | 79.78 |
| 1995-96 | 6.8 | 11.7 | 6.4 | 1561 | 91.45 | 71.73 |

*Source: Pakistan Economic Survey.*

*Note:* The nominal effective and real effective exchange rate indices are from Hasan (1998), Table 7.2 (p.339). The Index numbers relate to 4th quarter of the first year of the yearly intervals.
The GDP and Agricultural Value Added are real growth rates in percent per annum.

percent of the total output growth in the country. The chief source of growth in TFP has been the technological progress embodied in the high-yielding varieties of grains and cotton with supporting public investment in irrigation, agricultural research and extension (R&E), and physical infrastructure.

The results show that the performance in agricultural productivity was much higher during the second half of the1960s mainly due to the introduction of high yielding varieties of rice and wheat during this period. However, the growth in productivity tapered off in the first half of the 1970s due mainly to the politically induced institutional experiments. Gradual recovery in productivity growth was observed in the late 1970s and the early 1980s. Thereafter, an annual TFP growth rate of 2.4 percent has been sustained. Improvement in agricultural incentives, as reflected in the trends in the sectoral terms of trade, appears to have been a significant factor in evoking a sustained productivity response during this period.

With a macroeconomic policy environment that is largely conducive, what is needed at this juncture is a focused endeavour to deepen agricultural markets through public sector investments in marketing infrastructure and policy interventions to strengthen the role and management of agricultural markets. At the same time, the levels and efficacy of public expenditures for agricultural development, on a declining trend since the mid-1980s, need to be raised substantially. Public funding for agricultural research as a proportion of GDP, in particular, is much below levels required for an effectively functioning research system. According to a study by Nagy and Quddus (1998), an optimally funded agricultural research system in Pakistan needs to be funded at five to six times the present funding levels. “A research system funded at this level would approach international agricultural research standards, one that could deliver significant productivity and production increases. This would bring Pakistan’s funding of agricultural research closer to the funding level of 1.5 percent of Agricultural Gross Domestic Product (AGDP) recommended by the National Commission of Agriculture.” [Nagy and Quddus (1998), p.181].

***Annexures***

## ANNEX 1

## MEASUREMENT AND DATA ISSUES

The Tornqvist-Theil approximation to the Divisia Index (T-T) has been used for aggregation of outputs and inputs. The data on major and minor crops and wholesale and retail prices is available in the official documents. The major crops included are wheat, rice, cotton, sugarcane, maize, bajra, jowar, barley, and gram. The minor crops included are mung, mash, masoor, potatoes and onions. The livestock sector in the output index is represented by milk, beef and mutton.[11] As farm-gate prices were not readily available, they were estimated from wholesale prices reported in the official documents by assuming that farm-gate prices were uniformly 20 percent lower than the wholesale prices.[12] In a few instances, wholesale prices were not available for some items and for some time periods. In these cases, farm-gate prices were obtained by assuming a 30 percent difference between retail and farm-gate prices.

The labour input used in productivity studies for developed countries is a flow variable in terms of hours of labour per period of time. However, in the developing countries where collection of data at national and sectoral levels is still at a fairly rudimentary stage, labour input is usually approximated by its stock during the time

[11]These crops and livestock items cover about 71 percent of the value of gross product of agriculture (at current factor cost) in 1995-96. This coverage is greater for the major crops (88 percent) and livestock (74 percent) relative to minor crops. Only 13 percent of the minor crops could be covered due to non-availability of output and price data. However, it should be mentioned that the technological changes in agriculture appear to have affected the major crops and livestock more than the minor crops. Milk, beef and mutton quantities have not been reported for the period before 1970-71; therefore, they had to be extrapolated on the basis of per-capita consumption estimates, reported in national household surveys, and the size of the population.

[12]The Federal Bureau of Statistics (FBS) also uses this rule of thumb, when required. For example, as harvest prices for minor crops are generally not available, gross output in the minor crops sub-sector is calculated on the basis of prices that are assumed to be 80 percent of wholesale prices compiled by the Department of Agricultural Marketing and Grading. (*Fifty Years of Pakistan in Statistics*, a FBS publication.)

period in question i.e. the number of people employed in agriculture. As inaccuracies/biases are sure to enter into the analysis as a result of this approximation of a flow concept by a stock, in this study, the labour input series is measured as a flow variable i.e. the number of days worked by agricultural labour during the year.[13] Labour input is calculated by multiplying the number of agricultural labourers by the average annual workdays. Daily wage rates data have been obtained from various published sources.[14]

The land-input measure to be used in this study is the cultivated land area, which is calculated as a sum of net area sown and area left fallow that year.[15] The service flow from land is measured in terms of annual rental value of a hectare of land in Rupees. Annual rental series have been obtained from Farm Management Surveys carried out by government agencies. These relate mainly to the irrigated area in the Punjab province, the largest province with the largest value-added contribution to agriculture in Pakistan.

The use of capital as an input into agricultural production has grown in importance overtime against a backdrop of land and labour scarcities in the agricultural economies of many countries, though it is not as fully utilised in underdeveloped countries as in the developed countries. Capital assets typically enter agricultural production by rendering productive services. Therefore, from the point of view of production/productivity measurement, estimation of the flow of services emanating from capital stocks is more important than the stocks themselves.

The measurement of capital input in Pakistan's agriculture is also at a very elementary stage because of severe data constraints in this area. Wizarat (1981,1982) used a composite index of capital that included land rent, capital cost of private and public tubewells, number of tractors and livestock. The PIDE macroeconometric model (1983), on the other hand, opts for even less sophistication by simply using the number of tractors as a proxy for capital and all other auxiliary inputs. Khan

[13]While Khan (1997) has assumed average working days per year to be 265, Evenson, Pray and Rosegrant (1999) in their recent productivity study of Indian agriculture have used average annual workdays of 244, 244 and 215 for Haryana, Punjab and Rajasthan states of India. As the agricultural conditions in these states are very similar to those found in Pakistan, in this study an average of 250 workdays in a year is used.

[14]For the years 1959-60 to 1965-66 data reported in Chaudhry and Chaudhry (1992) has been used; data for the years 1966-67 to 1982-83 are from *ILO Yearbook of Labour Statistics*; and the data for the years 1983-84 to 1992-93 has been obtained from the *Pakistan Labour Gazette*.

[15]There are two measures of land available in the official statistics of Pakistan—cultivated land and cropped land. TFP studies of agriculture have used one or the other measure in their analyses [Hayami and Ruttan (1979); Fernandez-Cornejo and Shumway (1997) and Wen (1993)]. In the present study, cultivated land has been chosen as the appropriate measure of land input to keep the land input separate from the land-augmenting technological changes subsumed by cropped land. Both the arithmetic and T-T productivity indices give higher annual rates of growth with cultivated land than with cropped land. Productivity growth is lower with cropped land (arithmetic index 1.8 percent, T-T index 2 percent) as some of the output growth is due to multiple cropping.

(1997), however, has used tractors, tubewells and work animals as the main capital inputs into Pakistan agriculture.[16]

In this study, the capital stock index includes tractors, tubewells and working animals. The number of tractors data till 1978-79 has been obtained from Wizarat (1981). The data for number of tractors imported—which also includes domestically manufactured tractors—has been collected from the Ministry of Finance, Economic Survey (statistical supplement, 1996-97). The perpetual inventory method was used to calculate the stock of tractors (numbers) (from 1966-67 onwards) after taking into account depreciation of the stock and the net annual addition by imports and domestic manufactures.[17] The rate of depreciation is assumed to be 10 percent, considering that a ten-year life span for a tractor is quite reasonable. The same procedure could not be followed for tubewells as no reliable series for new tube-wells installed each year was available; so resort had to made to total number of tubewells reported in the Agricultural Statistics of Pakistan. The data on working animals has also been taken from the Agricultural Statistics of Pakistan. Tractor prices and average costs of installation of a tubewell have been collected from various official sources. The annual service flow from tractors and tubewells is assumed at 20 percent of the value of the stock of these capital items. This includes the rate of depreciation (10 percent) and the opportunity cost/debt service of the investment.[18] For draught animals, this has been assumed at 15 percent of the annual price series, following Khan (1997).

Purchased intermediate inputs (fertilisers, pesticides etc.)—which between themselves largely embody the Green Revolution technology—cannot be ignored in any productivity study which includes the Green Revolution and the subsequent period.[19] As the use of these inputs has grown at a very fast rate in the post Green Revolution period with the rapid intensification of agriculture, studies that do not

[16]In the developing countries, the data pertaining to capital inputs are not as reliable and extensive as in developed countries. Dholakia and Dholakia (1993) in a study of TFP for Indian agriculture for the period1950-51 to 1988-89, measure capital stock in terms of net capital stock valued at 1980-81 prices. This capital stock measure includes agricultural machinery, farm equipment and tools, transport equipment in farm business, land improvements, investment in public and private irrigation, farm houses, and stock of inventories including livestock. Wen (1993), in his study of TFP of China's farm sector, uses an even simpler measure of capital input that includes only the values of draft animals, non-draft animals, poultry and farm machinery. Evenson, *et al.* (1999) use bullocks and tractors as the primary sources of farm draught power in Indian agriculture.

[17]The capital stock at any one time represents the sum total of flow of accumulated investments over time after depreciation. The appropriate method for estimating the balance capital stock when it is being constantly replenished/augmented by new investments and at the same time being diminished by depreciation is Jorgenson's perpetual inventory method [Jorgenson (1974)].

[18]Evenson, *et al.* (1999) use 25 percent of the tractor price series as the shadow rental cost of a tractor. This includes both depreciation and debt service on the investment.

[19]Wizarat (1981) and Khan (1994) did not use any of the purchased inputs in constructing their input index as they used crop value-added as their output index. Khan (1997), however, includes only fertiliser as input.

properly account for these inputs are not likely to arrive at reasonable estimates of TFP growth in agriculture.

In the present study, the fertiliser inputs are made up of the consumption (off-take) of the three main types of fertiliser nutrients, namely nitrogen, phosphates and potassium. The quantity in nutrient/ton is obtained from the Economic Survey. The price data reported in Pakistan Economic Survey consist of price per bag of 50 kg. Given the known percent nutrient content of each marketed compound, this information has been used to convert the price per 50 kg bag into price/nutrient ton of the relevant nutrient. For example:

Price of Urea (46 percent N)/per 50 Kilo bag = Rs x
Price of Urea (46 percent N)/Metric Ton = Rs 20x (Using 1000kg = 1M.ton)
Price of Nitrogen/Ton = Rs 20x multiplied by 1/0.46

The effective price/nutrient ton was calculated by taking a weighted average of the prices of each nutrient calculated as above. Annual imports of pesticides in tons are reported in the official documents along with the value of the imports. The price/ton of imported pesticide can, therefore, be calculated from the value of import data. Assuming quantities to be imported are determined on the basis of anticipated usage, quantities imported serve as a proxy for quantities actually consumed.

Annex 2

*Indices of Agricultural GDP, Output, Input, and TFP, 1960–1996*[20]

| Year | Agricultural GDP (1980-81 Prices) Index | Output Index (T-T) | Input Index (T-T) | TFP Index (T-T) |
|---|---|---|---|---|
| 1960 | 100.0 | 100.0 | 100.0 | 100.0 |
| 1961 | 99.8 | 100.7 | 107.4 | 93.7 |
| 1962 | 106.0 | 108.3 | 108.0 | 100.3 |
| 1963 | 111.5 | 112.7 | 110.1 | 102.3 |
| 1964 | 114.3 | 113.2 | 112.6 | 100.5 |
| 1965 | 120.3 | 121.0 | 114.2 | 105.9 |
| 1966 | 120.9 | 115.8 | 116.0 | 99.9 |
| 1967 | 127.5 | 127.0 | 116.6 | 109.0 |
| 1968 | 142.4 | 138.3 | 118.0 | 117.2 |
| 1969 | 148.9 | 146.9 | 118.1 | 124.4 |
| 1970 | 163.1 | 158.4 | 120.6 | 131.3 |
| 1971 | 158.1 | 153.9 | 122.7 | 125.4 |
| 1972 | 163.6 | 161.5 | 123.6 | 130.7 |
| 1973 | 166.3 | 165.4 | 125.7 | 131.6 |
| 1974 | 173.2 | 172.8 | 127.0 | 136.1 |
| 1975 | 169.6 | 170.6 | 129.0 | 132.2 |
| 1976 | 177.1 | 181.4 | 133.9 | 135.5 |
| 1977 | 181.6 | 186.3 | 138.1 | 134.9 |
| 1978 | 186.3 | 193.1 | 140.8 | 137.2 |
| 1979 | 192.7 | 198.8 | 143.7 | 138.3 |
| 1980 | 205.7 | 213.6 | 147.4 | 144.9 |
| 1981 | 212.8 | 221.5 | 150.3 | 147.4 |
| 1982 | 222.8 | 229.3 | 152.6 | 150.3 |
| 1983 | 232.6 | 239.6 | 155.7 | 153.9 |
| 1984 | 221.4 | 229.3 | 155.8 | 147.1 |
| 1985 | 245.6 | 254.5 | 157.8 | 161.3 |
| 1986 | 260.2 | 276.5 | 166.5 | 166.1 |
| 1987 | 268.7 | 282.5 | 166.3 | 169.9 |
| 1988 | 276.0 | 294.3 | 169.8 | 173.3 |
| 1989 | 295.0 | 313.4 | 173.7 | 180.4 |
| 1990 | 303.9 | 322.7 | 177.6 | 181.7 |
| 1991 | 319.0 | 336.9 | 168.1 | 200.5 |
| 1992 | 349.3 | 366.6 | 173.6 | 211.2 |
| 1993 | 330.8 | 357.2 | 177.7 | 201.0 |
| 1994 | 348.1 | 369.7 | 185.7 | 199.1 |
| 1995 | 371.0 | 395.8 | 181.6 | 218.0 |
| 1996 | 392.5 | 420.2 | 183.3 | 229.2 |

[20]The output and input indices are based on the output and input aggregators defined in Equation (2), taking the exponents and chaining them.

## Annex 3

*Crop Output, Yields, Barter Terms of Trade, and Important Inputs, 1964-65–1975-76*

| Year | Index of Crop Production (1959-60 =100) | Wheat Yield (kg/h) | Rice Yield (kg/h) | Sugar Cane (kg/h) | Cotton (kg/h) | Net Barter Terms of Trade (1959-60 =100) | Water Avail-ability (MAF) | Fertiliser Off take (000 N/T) |
|---|---|---|---|---|---|---|---|---|
| 1964-65 | 128 | 863 | 996 | 37113 | 258 | 104.6 | N/A | 87.20 |
| 1965-66 | 127 | 760 | 945 | 37369 | 265 | 104.5 | 63.87 | 70.49 |
| 1966-67 | 135 | 811 | 969 | 33818 | 286 | 101.7 | 67.54 | 111.83 |
| 1967-68 | 157 | 1073 | 1056 | 37024 | 290 | 99.4 | 68.54 | 190.43 |
| 1968-69 | 168 | 1074 | 1307 | 40612 | 303 | 96.6 | 72.79 | 244.64 |
| 1969-70 | 186 | 1171 | 1480 | 42532 | 305 | 97.7 | 75.50 | 307.70 |
| 1970-71 | 174 | 1083 | 1464 | 36426 | 313 | 99.4 | 69.95 | 283.20 |
| 1971-72 | 183 | 1189 | 1554 | 36165 | 361 | 102.4 | 71.10 | 379.20 |
| 1972-73 | 188 | 1246 | 1574 | 37354 | 349 | 108.7 | 81.17 | 436.20 |
| 1973-74 | 196 | 1248 | 1624 | 37014 | 357 | 109.7 | 80.06 | 402.90 |
| 1974-75 | 187 | 1320 | 1443 | 31563 | 312 | 107.0 | 88.02 | 425.50 |
| 1975-76 | 199 | 1422 | 1531 | 36496 | 277 | 108.8 | 85.95 | 550.60 |

*Note:* The terms of trade index is the three year moving average computed by Qureshi (1987) using Lewis and Hussain methodology (1966) and 1959-60 weights. Water availability is measured in million acre-feet (MAF).

## Annex 4

*Yield Levels of Major Crops and Important Inputs, 1977–1998*

| Year | Wheat (kg/h) | Rice (kg/h) | Cotton (kg/h) | Sugar-cane (kg/h) | Cropped Area (Million Hectares) | Water Avail-ability (MAF) | Credit Disbursed (Rs (Million) | Fertiliser Off take (000'M/T) |
|---|---|---|---|---|---|---|---|---|
| 1977-80 | 1457 | 1583 | 304 | 37075 | 19.21 | 89.32 | 2285 | 879.2 |
| 1980-83 | 1628 | 1697 | 347 | 37841 | 19.72 | 98.54 | 5065 | 1134 |
| 1983-86 | 1658 | 1632 | 396 | 36496 | 20.06 | 103.7 | 10443 | 1322 |
| 1986-89 | 1719 | 1635 | 547 | 40198 | 20.74 | 112.2 | 15416 | 1747 |
| 1989-92 | 1885 | 1539 | 648 | 41883 | 21.66 | 119.6 | 14428 | 1888 |
| 1992-95 | 1973 | 1675 | 529 | 45304 | 22.15 | 127.45 | 18081 | 2159 |
| 1995-98 | 2103 | 1872 | 545 | 46925 | 22.77 | 128.35 | 24042 | 2524 |

*Source: Economic Survey, Agricultural Statistics of Pakistan.*

*Note:* kg/h is kilogram per hectare and MAF is million acre feet.

## Annex 5

*Terms of Trade of Agriculture Sector in Pakistan, 1990-91–1999-2000*

| Year (1) | F (2) | M (3) | Ratio (4) | F+R (5) | M+Fu+C (6) | Ratio (7) | BTOT (8) | Index (9) | ITOT (10) |
|---|---|---|---|---|---|---|---|---|---|
| 1990-91 | 100.00 | 100.00 | 1.00 | 100.00 | 100.00 | 1.00 | 100.00 | 100.00 | 100.00 |
| 1991-92 | 110.87 | 108.15 | 1.03 | 109.75 | 108.23 | 1.01 | 101.00 | 109.50 | 110.60 |
| 1992-93 | 122.64 | 112.80 | 1.08 | 121.71 | 111.35 | 1.09 | 109.00 | 94.71 | 103.23 |
| 1993-94 | 139.68 | 131.47 | 1.06 | 147.45 | 129.36 | 1.14 | 114.00 | 105.23 | 119.96 |
| 1994-95 | 164.77 | 151.55 | 1.09 | 171.91 | 149.48 | 1.15 | 115.00 | 106.57 | 122.56 |
| 1995-96 | 184.13 | 164.94 | 1.11 | 186.30 | 166.62 | 1.12 | 112.00 | 111.72 | 125.13 |
| 1996-97 | 205.94 | 184.62 | 1.12 | 210.92 | 190.23 | 1.11 | 111.00 | 100.12 | 111.13 |
| 1997-98 | 220.78 | 189.17 | 1.17 | 226.78 | 199.92 | 1.13 | 113.00 | 104.52 | 118.11 |
| 1998-99 | 235.68 | 195.02 | 1.21 | 245.89 | 209.23 | 1.18 | 118.00 | 101.95 | 120.30 |
| 1999-00 | 236.82 | 203.80 | 1.16 | 231.99 | 217.07 | 1.07 | 107.00 | 105.54 | 112.93 |

*Notes:*

1. Column 2: 'F' is the price index of food.
2. Column 3: 'M' is the price index of manufactures.
3. Column 4: F/M Ratio.
4. Column 5: 'F+R' is the combined price index of food and raw material.
5. Column 6: 'M+Fu+C' is the combined price index of manufactures, fuels , and construction.
6. Column 7: (F+R)/(M+Fu+C) Ratio.
7. Column 8: Barter Terms of Trade (BTOT) of agriculture (Column 7 × 100).
8. Column 9: Index of agricultural production (output).
9. Column 10: Income Terms of Trade (ITOT) of agriculture (Column 8 × 100).

## Annex 6

*Relative Purchasing Power of Major Crops in Pakistan, Selected Years*

| Year | Wheat | | Cotton (Seed) | | Sugarcane | | Rice IRRI 6 (Paddy) | | Rice Basmati (Paddy) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | U | DAP | U | DAP | U | DAP | U | DAP | U | DAP |
| 1990-91 | 1.39 | 1.78 | 0.60 | 0.77 | 10.26 | 13.11 | 2.13 | 2.72 | 1.09 | 1.39 |
| 1994-95 | 1.18 | 1.90 | 0.44 | 0.72 | 9.22 | 14.86 | 1.83 | 2.95 | 0.89 | 1.44 |
| 1999-00 | 0.86 | 1.73 | 0.33 | 0.64 | 7.39 | 14.75 | 1.40 | 2.80 | 0.74 | 1.48 |

*Note:* Purchasing power is measured in terms of crop output (in kgs) required to purchase one kg. of Urea and DAP ( phosphate fertiliser).

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