MACRO DETERMINANTS OF TECHNOLOGICAL PROGRESS IN AGRICULTURAL SECTOR OF PAKISTAN

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Abstract

The aim of the current study is to investigate the macro determinants of the technological progress in the agricultural sector of Pakistan. Variables of the study are technological progress (TFP), infrastructural development (INFRA), research and development (R&D), human resource development (EDU) and credit disbursement (CRD). Time series data have been used which is from the period of 1961-2013. Total factor productivity index has been used as proxy for the technological progress. The tremendous growth in the TFP has been observed during the decade of 60’s and lowest rates during the decade of 70s and in 2000. Further study used ARDL model for finding the significant long and short run relationship among the variables. The results showed that there is positive and significant relationship between the education (EDU) and technological progress (TFP) both in long and in short run. Similarly infrastructure (INFRA) and TFP has also positive and significant relationship both in short and in long run. But the results of the research and development (R&D) showed that in short run it is positive and significant and in long run it has insignificant relationship with the TFP. On the contrary, credit disbursement (CRD) has positive and insignificant relationship with the TFP in short and in long run. Findings of the present study concluded that technological progress has been positively affected by the macro economic variables and also by the efficiently utilization of inputs.

Keywords: Autoregressive distributive lag model, Technological progress, human resource development, credit disbursement, infrastructure development and research and development.
Introduction

The growth in the production of agricultural sector has played an important role in the development of economies. Economist has studied the growth of production in which they highly observed the sources of productivity growth and also studied the differences in production among different economies. The importance of productivity growth and its study can easily be mapped to output of agricultural products in order to meet the demand. The average annual growth of Pakistan’s agricultural GDP is about 3.46 percent. In comparison to the last six periods, this has compressed the growth of population with 2.58 percent (Pakistan 2004). Furthermore, this rate of growth in agriculture has been persistently maintained by technological development, personified in the high resilient varieties of cotton and grains, with supporting public investment in agricultural research and extension, physical infrastructure and irrigation (Ali and Iqbal, 2005).

In 21st century the agriculture sector of Pakistan is facing a great challenge in terms of food sanctuary and endurance in the globalized world under the world trade organization scenario. But these challenges will be overcome by the aforementioned factors (technological development, investment in irrigation, research and development and in infrastructure development) in the agriculture sector. This will ultimately reduce poverty in rural areas and will fulfill food demands (Chaudhry, 2009). The demand for food is increasing due to low per capita income. An absence of suitable policy for sustaining the technological progress will impose a high growth in imports of vital food items. This will increase financial burden directly on foreign exchange income of a country (Zaidi, 1999).

For the improvement in the production of agricultural sector it needs good investment in research and development program in order to invent advanced technologies. Investment in educating farmers is necessary in order to initiate awareness about the technological opportunities. Investment in infrastructure will be helpful for the farmers to efficiently and timely access the markets. In addition, it requires an economic environment favourable enough for appropriate investments in capital by the large and small land farmers (Azam, Bloom et al., 1991).

1.2 Neo classical growth theory for the technological progress
In 1956 Solow present a new classical growth theory in which he explained for the first time that growth in total output was effected by the technological change. First he worked on the Cobb Douglas production model and considered the two factor production theory which is also known as classical growth theory. In classical growth theory, labour and capital were considered as a two factors of production. During the study Solow found residuals which was left after the calculation of production model. The residual was called as a technical change. After this Solow (1957) worked on the technical change and aggregate production function. In his paper he present a model which is known as Solow residual production model. In this model he used three factors labours, capital and technical change. Therefore this model is also known as exogenous growth model because technical change was considered as an exogenous factor. The reason for taking the technical change or residuals in the model was to know that how much output growth will be explained by the technical change factor. He conducted his worked on the U.S economy in 1957 and results showed that the model leaves a large unexplained residual, it suggesting that capital and labour explain only a fraction of per capita output growth. In this way he criticized the work of Harrod(1939) and Domar(1946) and developed a new growth theory. The assumption of this theory are the constant return to scale. The constant return to scale means is that the ratio of input to output remain constant. Perfect factor market competition. Complete information of economic factors. Important point for the conduction of this theory is that constant return to scale assumption is only for the labour and capital in the model and it is not compulsory for the technical change variable in the model. The reason are the improvement in technology, shift the production function line therefore the increase in the technological change which is also known as the total factor productivity increase the marginal productivity of inputs evenly.

The current study are conducted on the technological progress in agricultural sector of Pakistan and its macro determinants therefore this theory justify that yes technological progress are contributed in the productivity growth and the efficiently utilization of the total input factors shifts our production function. Therefore, our study is based on the neo classical growth theory.

1.3 Objectives of the Study

1)To calculate the technological progress on the basis of total factor productivity growth in Pakistan

2)To find the effect of the macroeconomic determinants on the technological progress
1.4 Hypothesis

H₀: There is insignificant relationship between the macro-economic variables and technological progress

H₁: There is significant relationship between the macro-economic variables and technological progress.

Literature review

Before 1957 there was a great debate on the two questions. First question stated that how far the economic progress is achieved by the development in human capital (labour) and by the growth in other physical factors. While, second question stated, how much growth in economic has been stimulated by the institutional and technological change. In the view of economist, it is a fact that physical and labour capital has significant influence on the economic growth. But, most of the studies showed that persistent high growth is based on the constant institutional and technological change (Bhatia, 1990). In economics one of the assumptions of growth is constant return to scale and competitive factor arcades which calculates the progress rate by considering only the variation in human capital and physical factor. It results the abnormalities of the real growth rate from the implicit growth rate. These abnormalities are known as total factor productivity growths which are resulted from the institutional and technological change (Mueller, 1998). Solow(1957) derived equation from the Cobb Douglas function and called it Solow residual function. Solow residual function has been used in many literatures for calculating the Total factor productivity.

Wizarat (1981) has worked on the technological change in agricultural sector of Pakistan from 1953-1954 and 1978-1979 in which she used only value added crops and growth accounting approach for calculating the TFG. Her results showed that 84% output has increased due to the change in technology, while 16% increase is enforced by the total inputs. Khan (2006) has followed the approach of Solow (Cobb Douglas production function), he worked on the macro determinants of TFP in all sectors of Pakistan, in which he
covered samples from 1960 to 2003 and concluded his results. It states that, capital is an important factor in the growth of output. This way his results are also aligned with Wizarat (1981) that not only inputs are responsible for the increase in outputs but there are other factors too. These factors are foreign direct investment, financial sector development and macroeconomic stability. They affected the growth of TFP.

Akanbi (2011) has followed the work of Khan (2006) and he used the Cobb-Douglas production function for calculating the growth of TFP. He worked on Nigerian economy and concluded his results that not only inputs are important factors of the growth while there are other macro-economic variables such as financial development, human level development and macro-economic instability. They also increase the output with existence of the conventional inputs (labour and capital).

Chaudhry (2009) has compared the growth of manufacturing sector and agricultural sector in Pakistan and he used Cobb Douglas production function for the estimation of TFPG, he presented in his analysis that growth in agricultural sector is highly driven by the increase in labour but there are still other factors which are regulator of the sustained growth in Pakistan.

Many researchers has used torn-quest tail index as a good and efficient tool in calculating TFP. Rosegrant, Evenson et al. (1993) have used Tornqvist-Theil (T-T) methodology for the calculation of technological change in Pakistan. They choose only crop sector for the analysis. Their results showed that among three provinces, total factor productivity has grown rapidly in the early stage of Green revolution but after this period the growth decline rapidly and they concluded that in the whole study TFP has found 33% out of the total output growth in crop sector.

Ali and Iqbal (2004) and Ali, Mushtaq et al. (2008) both has used the same tool for the calculation of TFPG. Ali and Iqbal (2004) has investigated two sectors livestock and crop.
He concluded his results that 2.3% growth of TFP has been observed from the 1960-1996, he said that it is 58% to the total output growth. The reasons behind agricultural growth from 1960-1996 are the high quality of grain and speculation in the road development, research and development and in irrigation system.

During 1970 he observed poor performance of agriculture. The major causes he explained in his paper are the heavy rains, floods and the separation of the Bangladesh. In the same way Ali, Mushtaq et al. (2008) has investigated the livestock and crop sector in Pakistan from the 1970-2006. He also observed poor performance of agriculture in 1970, he further explained that in 1970, 33% TFP has contributed to the total output growth while during the 80’s and 90’s TFP growth rate reached up to 83% to the total output. The major causes for both the growth and decline are explained in his paper. They are the weather, institutional factors and government policies.

Further Nadeem, Javed et al.(2010) has conducted research on the TFPG and performance in the livestock sector of Punjab. He also used the Tornqvist-Theil (T-T) index for the calculation of technological change. He concluded his results with negative growth rates from the 1970 to 1978 due to the poor government policies but he interpreted that overall performance of TFP was recorded 1.54 which contributed 46% to the total output growth of the livestock during the study period. He recommended that government should focus on the technological factor in the livestock sector which had been neglected from the start, like good variety of fodder crops and high yielding breeds for the milk and meat production.

Kiani (2008) has conducted research on the TFP and research in agriculture sector of Khyber Pakhtunkhwa province of Pakistan. She used T-T index for the calculation of TFP. Her results are aligned with the results of Ali and Iqbal (2004). She focused on significant relationship between the Research and Development and TFP. Her analysis showed positive
and significant results and study concluded that when research expenditure increases one percent it increased 43 percent TFP.

Fan (1997) has also used T-T approach in his study but he used three sectors livestock, crop and fishery in china agriculture. He concluded his work that TFP has highly affected by the investment in research, infrastructure and irrigation so the government should increase the investment in the agriculture sector for the efficient growth in these sectors.

**RESEARCH METHODOLOGY**

3.1 **Population and sample of the study**

Population of the current study are the all sectors of Pakistan. The sample of this study are all sub sectors of agriculture in Pakistan like crop, livestock, forest and fishing.

3.2 **Data collection and sources**

The current study has used the secondary data. The examination of technological progress in each subsector is perplexing because of data restrictions but an effort has been made to acquire a reliable dataset. The data have been collected from 1961-2013 from different sources including the Agricultural Statistics of Pakistan issued by Pakistan Bureau of Statistics (PBS), Labor Force Surveys of Pakistan issued by PBS, the Economic Surveys of Pakistan issued by Ministry of finance and world development indicator (WDI).

3.3 **Variables of the Study**

3.3.1 **Depended variable**

Technological progress has used as a dependent variable in the current study. TFP index has been used as a proxy for measuring the dependent variable. There are four type of indices for measuring total factor productivity growth including: The Paasche index, Laspeyres index, Fisher Quantity index, and Törnqvistthiel index.

All indexes has their own uses but present study used Tornqvist-Theil (T-T) index. T-T index has many advantages over the above mention indexes. The first importance of this index is that no limits has been impose on the replacement possibilities among the inputs. It mean that fever limits have between the TFP and data (Alaston, Norton et al., 1995).
importance of this index is that it is precise for the linear homogeneous Trans log production function. Third and very important point of this index is that it incorporated the current factor prices for measuring the individual share of the factors and therefore it has been helpful in finding variation in the quality of inputs and outputs. This index has provided constant collection of input and output under the assumption of constant return to scale, competitive factor arcade, output-input separability and Hicks-neutral technical change (Christensen, Cummings et al., 1981., Antle and Capalbo, 1988). This index have been widely used by national statistical agencies and in the economics literature (Ali and Iqbal, 2004., Ali, Mushtaq et al., 2008).

Technological progress is the dependent variable and Total factor productivity (TFP) index has been used as a proxy for the dependent variable. TFP consist of all inputs and outputs which are explained below in detail. The proxy for the technological progress is TFP (Hayami, Ruttan et al., 1978., Crafts, 2003., Jajri, 2007., Akanbi, 2011) which is calculated by the Tornqvist-Theil (T-T) index (Fan 1997, Ali, Mushtaq et al. 2008)

The Tornqvist-Theil (T-T) index is defined as

\[
\ln \left( \frac{TFP_t}{TFP_{t-1}} \right) = \frac{1}{2} \sum (R_{kt} + R_{kt-1}) \ln \left( \frac{Q_{kt}}{Q_{kt-1}} \right) \quad \frac{1}{2} \sum (S_{it} + S_{it-1}) \ln \left( \frac{X_{it}}{X_{it-1}} \right) \quad \ldots \ldots \quad (1)
\]

Where:
- \( R_{kt} \) is the share of k output in total revenue.
- \( Q_{kt} \) is output k.
- \( S_{it} \) is the share of input i in total input cost.
- \( X_{it} \) is input i.

In this specification, revenue shares for the output index and cost shares for the input index are updated every year. Specifying the index equal to 100 in the base year and accumulating the measures based on equation (1) provides the TFP index (Ali et al, 2008).

### 3.3.2 Independent variables

All those variables which explain changes in the dependent variable are known as independent variables.
a) **Human Capital Development**

Human capital development has used as an independent variable, it is often regarded as the accumulation of education, and educational change influences markedly productivity and agricultural growth. Investment in education and on workshops for the human development increased the efficiency in labours. Primary school enrolment has been used as a proxy in the current study (Khan, 2006., Ali, Mushtaq et al., 2012).

b) **Infrastructural Development**

Second independent variable in the study is infrastructure development. Shenggen, R et al. (1999) explained that infrastructural development seem to be the significant determinant while studying productivity growth of agriculture in India. In china Shenggen and Zhang (2004) also revealed the high importance of infrastructural development in productivity of rural areas. Infrastructural development were calculated by road length Ali, Mustaq et al. (2012). Road length has used in the current study as a proxy.

c) **Credit Resources**

Third explanatory variable of the study are credit resources. Easy contact to credit not only improves economic growth but also the productivity of organizations and adds to TFP of the overall economy. Ali, Mushtaq et al. (2012) has used credit disbursement as a percentage of agricultural GDP ratio as a proxy for credit resources. The present study has used credit disbursement to the agriculture sector as a percent of agricultural GDP as a proxy for financial sector development in agriculture.

d) **Research and Development**

Research and Development are the last variable of the current study. It is a positive and significant explanatory variable of the TFP econometric mode. Fan (1997) and Kiani (2008) has explained in their papers that investment in research field will increase the TFP rate. Therefore the current study used the R&D variable in order to explain the technological progress. It is simply calculated by taking log of expenditure of research and development (R$D) in agricultural sector of Pakistan (Khan, 2006., Akanbi, 2011).

3.4 **Econometric Model of the Study**
\[ TFP_t = \alpha_0 + \alpha_1 \log \text{INFRA}_t + \alpha_2 \log \text{R&D}_t + \alpha_3 \log \text{EDU}_t + \alpha_4 \log \text{CRD}_t + \epsilon \]

Where,

TPF = Total factor productivity index (Fan 1997, Ali, Mushtaq et al. 2008)

LINFRA = log of road length (Ali, Mushtaq et al., 2012).

LR&D = log of research and development (Khan, 2006, Akanbi, 2011).

LEDU = log of primary schools enrollment (Ali, Mushtaq et al., 2012).

LCRD = log of credit disbursed to agriculture sector as a percent of agricultural GDP (Ali, Mushtaq et al., 2012).

### 3.5 Statistical Tools of the Study

#### 3.5.1 Unit root test

When a researcher talks about time series data then it is important to check first the unit root problem in the given data. One of the characteristics of time series data is that it usually follow random walk. This random walk means that it does not have constant mean or constant variance or both. This unit root issue in the data is due to the known fact (as its name indicates “time series”), the time factor such as bad and good times, boom times, natural disasters and cyclical factors etc. to sum up, this time series is dependent on the changing situation/environment and dynamic state of the economy (Gujarati, 2009). One cannot predict future changes or activities exactly, therefore there is a big complexity involved in forecasting future changes and that is why as time passes there comes sudden and unexpected changes in the data which leads to the problem of unit root. Thus if a researcher wants to co-integrate variables the data must be stationary and integrated of order one, one i.e. I(1). In order to diagnose the unit root problem one well know test are Augmented dicky-fuller (ADF) test has used (Dickey and Fuller, 1981). The ADF test equations (in difference form) with trend and without trend are given as follows.

\[ \Delta Z_t = \gamma_1 + \gamma_2 t + \beta Z_{t-1} + \pi \sum_{t=1}^{k} \Delta Z_{t-1} + \mu_t \quad (3.1) \]

\[ Z_t = \gamma_1 + \beta Z_{t-1} + \pi \sum_{t=1}^{k} \Delta Z_{t-1} + \mu_t \quad (3.2) \]

The equation (3.1) \( \gamma_1 \) shows a constant and \( \gamma_2 \) shows a trend term while the equation 3.2 lack the trend term where \( \gamma_1 \) shows only a constant. In above equations \( \Delta \) is the 1\textsuperscript{st} difference operator, \( \mu_t \) is an error term and the coefficient \( \beta = (\rho - 1) \). For above equations the null hypothesis is \( H_0: \rho = 1 \) or \( \beta = 0 \) which means that the time series are non stationary.
or having a unit root. The alternative hypothesis will be $H_1: \beta < 0$, that is, the time series is stationary and does not have unit root. In ADF test lagged values is taken in order to minimize the error term in shape of residual value. Akaike information criterion (AIC) is used for selecting appropriate number of lags for which the value of criterion is minimized.

### 3.5.2 ARDL model

Autoregressive distributed lag model approach (ARDL) has been developed by the Pesaran and Shin (1998). It is a dynamic model which is used to calculate the coefficients for finding the co-integration among variables. Further ARDL approach has been extended by the Pesaran, Shin et al. (2000), Pesaran, Shin et al. (2001). ARDL approach has many benefits as compared to the traditional approaches toward co-integration. a) It gives optimum results with small sample data as compared to Engle and Granger (1987), Johansen and Juselius (1990) and Phillips and Hansen (1990) approaches of co-integration. b) ARDL uses general to specific approach for finding significant relationship among the variables if the variables becomes insignificant in general model (unrestricted error correction model) then study has used specific model (restricted error correction model) by dropping the highly insignificant values from the model (Laurenceston and Chai, 2003). C) All variables should be on the integration of order I(0) and I(1) but none on the I(2) d) Bounds test toward co-integration is being applied irrespectively the order of integration of the variable I(1) or I(0). e) The short-run and long-run coefficients of the model are projected instantaneously (Aregbeyen and Ibrahim, 2012).

The current study used this model for finding the long run and short run relationship among the variables. Following steps were followed in the estimation of the ARDL model.

1. Conclude the appropriate lag structure for the model
2. Formulate an "unrestricted" error-correction model (ECM).
3. Breusch-Godfrey Serial Correlation LM Test has used for finding the serial correlation for the error term in the model
4. Make sure that the model is "dynamically stable".
5. Perform a "Bounds Test" to check the co-integration between the variables.
6. If the outcome at step 5 is positive, calculate a long-run "levels model", as well as a separate ECM (long run multiplier).
7. After step 6 then we used to measure short-run dynamic effects, and the long-run equilibrating relationship between the variables.

The general form of ARDL model

\[ \Delta TFP = \beta_0 + B_1 TFP_{t-1} + B_2 LNRS_D_{t-1} + B_3 LNEDU_{t-1} + B_4 LNINFRA_{t-1} + B_5 LNCRD_{t-1} + \sum_{i=0}^{k} B_2 \Delta LNRS_D_{t-1} + \sum_{i=0}^{k} B_3 \Delta LNEDU_{t-1} + \sum_{i=0}^{k} B_4 \Delta LNINFRA_{t-1} + \sum_{i=0}^{k} B_5 \Delta LNCRD_{t-1} + \lambda ECT_{t-1} + \epsilon \]

eq 02

Where, TFP denotes total factor productivity index which shows technological progress, LNRS_D denotes log of research and development, LNINFRA denotes log of road length, LNEDU denotes log of education and LNCRD denotes log of credit disbursement. The first difference operator is denoted by \( \Delta \), constant term is represented by \( \beta_0 \), \( k \) represents the lag length criterion, time trend is shown by \( t \), \( \lambda \) is the coefficient for measuring the speed of adjustment, \( \epsilon \) is the error term.

**For long run**

\[ TFP = \beta_0 + B_1 TFP_{t-1} + B_2 LNRS_D_{t-1} + B_3 LNEDU_{t-1} + B_4 LNINFRA_{t-1} + B_5 LNCRD_{t-1} + \epsilon \]

\( t \)

**For short run**

\[ \Delta TFP_t = \beta_0 + \sum_{i=0}^{k} B_1 \Delta LNRS_D_{t-1} + \sum_{i=0}^{k} B_2 \Delta LNEDU_{t-1} + \sum_{i=0}^{k} B_3 \Delta LNINFRA_{t-1} + \sum_{i=0}^{k} B_5 \Delta LNCRD_{t-1} + \lambda ECT_{t-1} + \epsilon \]

Bound test is used on the long run estimates in the general model, it showed the existence of long run relationship among the variables.

The null hypothesis for the bound test is there is no co-integration among the variables

\( H_0: \beta_1 = \beta_2 = \beta_3 = \beta_4 = \beta_5 = 0 \)

The alternative hypotheses is there is co-integration among the variables

\( H_a: \beta_1 \neq \beta_2 \neq \beta_3 \neq \beta_4 \neq \beta_5 \neq 0 \)
The ARDL bound test is based on the Wald-test (F-statistic). Two bound critical values are given by Pesaran, Shin et al. (2001) for the co-integration test. The upper bound assumes that all the variables are I(1) meaning that there is co-integration among the variables. The lower critical bound accepts all the variables as I(0) meaning that there is no long run relationship between the examined variables. When the computed F-statistic is greater than the upper bound critical value, then the H0 is rejected (the variables will be having long run relationship). When the F-statistic is below the lower bound critical value, then H0 cannot be rejected (there is no long run among the variables). When the computed F-statistics falls between the lower and upper bound, then the results are indecisive.

Where ECT (-1) is a term which is calculated through the long run equilibrium relationship, it is also known as the long run multiplier. The ECT (-1) term must be negative and highly significant and it must be in the range of 0 to -1. 0 implies that there is no convergence after a shock while -1 showed that there is perfect convergence. The sign of the ECMt–1 must be negative and significant to ensure convergence of the dynamics to the long-run equilibrium (Pesaran, Shin et al., 2001).

The stability test cumulative sum (CUSUM and the cumulative sum of squares (CUSUMQ) which were introduced by the Brown, Durbin et al. (1975) has been used for finding the stability of its parameters. The test CUSUM shows if the cumulative sum goes outside the two critical lines, then the model is not free from instability. Similarly, CUSUMQ, which is based on squared recursive residuals, goes outside the critical lines, and then the model is instable.

RESULTS AND DISCUSSION

Econometric analysis

To analyse the effect of the macroeconomic determinants on the technological progress (TFPG), ARDL approach has been conducted for finding the underlying relationship among the variables. The current study has time series data therefore unit root problem is significant in the series for the individual variable. Augmented dickey fuller test are conducted for realizing the unit root problem in the data. The results of the unit root test are depicted below.
Unit root results

In time series analysis, before running the ARDL model, variables must be tested for unit root problem. For this purpose, the current study conducted the Augmented Dickey Fuller test with constant, constant and trend, and without constant and trend models. The assumption of co-integration is that all variables should be on I(1), (Gujarati, 2009). After running the ADF test when some variables are on I(0) and some are on I(1) then ARDL model will be used for finding the underlying relationship among the variables (Pesaran and Shin, 1998). The results are presented below.

Table 4.2.1.1: ADF test results for stationarity at level (constant and trend)

<table>
<thead>
<tr>
<th>Variables</th>
<th>ADF level (constant and trend)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>T-statistics calculated values</td>
</tr>
<tr>
<td>TFP</td>
<td>9.048989</td>
</tr>
<tr>
<td>LNINFRA</td>
<td>1.071683</td>
</tr>
<tr>
<td>LNR$D</td>
<td>0.733086</td>
</tr>
<tr>
<td>LNEDU</td>
<td>2.369502</td>
</tr>
<tr>
<td>LNCRD</td>
<td>2.334560</td>
</tr>
</tbody>
</table>

The ADF test has been conducted for the significance of the unit problem in the given data. The null hypothesis of the ADF test is ‘the data has unit root problem’ while the alternative hypothesis is ‘the data has no unit problem’. The above results revealed that there are mix order of integration, TFP is stationary at level because the P value is less than 0.05%. The other three variables such as LNINFRA, LNR$D, LNEDU and LNCRD is non-stationary at level because the P-value for all the four variables are greater than 0.05% in the table therefore null hypothesis is rejected and alternative hypothesis is accepted (Kwiatkowski, Phillips et al. 1992). Now the next step is to check the unit root problem in the non-stationary variables at the first difference. The TFP variable is excluded from the table below, because it is significant at level, therefore no need to check unit root at first difference. The results for LNINFRA, LNR$D, LNEDU and LNCRD at first difference is present in the table 4.3.
ADF test results for stationarity at First difference (constant and trend)

<table>
<thead>
<tr>
<th>Variables</th>
<th>ADF 1st Difference(constant and trend)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>T-statistics calculated values</td>
<td>T-statistics critical values at 5%</td>
</tr>
<tr>
<td>LNINFRA</td>
<td>3.781557</td>
<td>2.941145</td>
</tr>
<tr>
<td>LNR&amp;D</td>
<td>6.493658</td>
<td>2.935001</td>
</tr>
<tr>
<td>LNEDU</td>
<td>4.905044</td>
<td>2.935001</td>
</tr>
<tr>
<td>LNCRD</td>
<td>5.323590</td>
<td>2.935001</td>
</tr>
</tbody>
</table>

In table-4.3, results of the variables at first difference are presented. ADF test has been conducted with constant and linear trend both for finding the unit root problem at the first difference in above variables. LNINFRA result showed that it is significant at first difference because the calculated value of T test is greater than the critical value at 5%. P value is also less than 0.05% and support the T test decision. Similarly LNR&D, LNEDU and LNCRD are also stationary at first difference because their T test value is greater than the critical value at 5% and p value is also less than 0.05% in the table-4.3.

The ADF test results revealed that one variable is significant at level and the other four variables are significant at first difference, this means that no variable has been found at integration of order two. The assumption of the ARDL model towards co-integration is I(0) and I(1) and the above results fulfilled this assumption, so the next step is to undertake the ARDL model for the estimation of the short run and long run estimates in order to find the underlying relationship among variables.

**ARDL model lag selection**

To find the underlying relationship among variables, the study conducted ARDL approach toward the co-integration. Now the study will first find appropriate lags by using Schwarz Bayesian Criterion (SBC), Hannan-Quin (H.Q) and Akaike Information Criterion (AIC). According to the Pesaran, Shin et al. (2001) and Gujarati (2009) the minimum value of AIC, SBC and H.Q should be selected for the appropriate ARDL model. The current study used eviews 9 version for the calculation in which the lags order are automatically depicted by the graph. According to the AIC criteria the appropriate lag order for the model is (2, 2, 4, 2, and 0). TFP lag order is 2, LNEDU lag order is 2, LNR&D lag order is 4, LNINFRA lag order is 2 and LNCRD is 0. Graph for the lags order is presented below.
The ARDL model is calculated on the basis of the AIC lag selection criteria. Basically the results of the model showed the existing relationship among the variables. The model is calculated on the basis of the equation 02, in which coefficient are not restricted. The results are given in the table-4.4.

**General Model of ARDL for TFP, R$D, education, infrastructure & credit disbursement.**

<table>
<thead>
<tr>
<th>Regressors</th>
<th>Coefficient</th>
<th>Standard error</th>
<th>T-ratio</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>TFP(-1)</td>
<td>-0.791629</td>
<td>0.171483</td>
<td>-4.616382</td>
<td>0.0001</td>
</tr>
<tr>
<td>TFP(-2)</td>
<td>-0.354498</td>
<td>0.116308</td>
<td>-3.047939</td>
<td>0.0055</td>
</tr>
<tr>
<td>LNR$D$</td>
<td>0.231187</td>
<td>0.226874</td>
<td>1.019012</td>
<td>0.3184</td>
</tr>
<tr>
<td>LNR$D$(-1)</td>
<td>-0.285848</td>
<td>0.254711</td>
<td>-1.122244</td>
<td>0.2729</td>
</tr>
<tr>
<td>LNR$D$(-2)</td>
<td>0.129883</td>
<td>0.273817</td>
<td>0.474342</td>
<td>0.6395</td>
</tr>
<tr>
<td>LNR$D$(-3)</td>
<td>0.251010</td>
<td>0.278905</td>
<td>0.899983</td>
<td>0.3771</td>
</tr>
<tr>
<td>LNR$D$(-4)</td>
<td>0.676547</td>
<td>0.227423</td>
<td>2.974840</td>
<td>0.0066</td>
</tr>
<tr>
<td>LNEDU</td>
<td>0.483523</td>
<td>0.820028</td>
<td>0.589642</td>
<td>0.5609</td>
</tr>
<tr>
<td>LNEDU(-1)</td>
<td>-0.670521</td>
<td>1.164768</td>
<td>-0.575669</td>
<td>0.5702</td>
</tr>
</tbody>
</table>
The above table shows the results of the ARDL general model in which coefficient are not restricted. Dependent variable in the model is TFP. The results showed that P value of research and development is less than 0.05% at lag 4 and the value of coefficient is positive so it depicted that there is positive and significant relationship between research and development and TFP. Similarly the p value of infrastructure is also less than 0.05% and its coefficient is positive so it can be concluded as that there is positive and significant relationship between the infrastructure and TFP. The p value of education is also less than 0.05% and its value of coefficient is positive therefore there is positive and significant relationship between education and TFP. But the P-value of credit disbursement (LNCRD) is greater than 0.05% therefore LNCRD is positive but insignificant relationship with the TFP. R-squared is also known as the coefficient of determination, it basically depicted that how much the model explained the variation in the dependent variable. The coefficient of determination ranges from 0 to 1. When the coefficient is near to zero, it mean no variation has been explained by the model in the dependent variable. The coefficient of R-squared is 0.81, it mean that 81% variation has been explained in the dependent variable by the model, and it also implies that the model fit the data better(Brooks, 2008). F statistics value showed that the model is highly significant. The Durban Watson values ranges from the 0 to 4. The value near 2 showed that there are no correlation found in the error term.

**Bound test**

Bound test is used on the long run estimates in the general model, it showed the existence of long run relationship among the variables. The null hypothesis for the bound test is there is
no co-integration among the variables while the alternative hypotheses is there is co-integration among the variables.

Two bound critical values are given by Pesaran, Shin et al. (2001) for the co-integration test. The upper bound assumes that all the variables are $I(1)$ meaning that there is co-integration among the variables. The lower critical bound accepts all the variables as $I(0)$ meaning that there is no long run relationship between the examined variables.

In each case there are always two bounds, lower bound and upper bound. When the calculated value of the bound test is less than the lower bound then will accept the null hypothesis that there is no long run relationship among variables. But when the calculated value of the bound test is greater than the upper bound then will accept the alternative hypothesis that there is long run relationship among the variables. Critical bounds are used from Narayan (2005) and from Pesaran, Shin et al. (2001) with respect to sample size. The results of the bound test is presented in the table 4.5.

**Bound test result.**

<table>
<thead>
<tr>
<th>t-statistics</th>
<th>value</th>
<th>k</th>
</tr>
</thead>
<tbody>
<tr>
<td>F-statistic</td>
<td>14.62200</td>
<td>4</td>
</tr>
<tr>
<td>p-value</td>
<td>0.000000</td>
<td></td>
</tr>
</tbody>
</table>

**Critical values of the bound test Table**

<table>
<thead>
<tr>
<th>significance</th>
<th>I(0)</th>
<th>I(1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10%</td>
<td>2.2</td>
<td>3.09</td>
</tr>
<tr>
<td>5%</td>
<td>2.56</td>
<td>3.49</td>
</tr>
<tr>
<td>2.50%</td>
<td>2.88</td>
<td>3.87</td>
</tr>
<tr>
<td>1%</td>
<td>3.29</td>
<td>4.37</td>
</tr>
</tbody>
</table>

As the above table showed that F statistics value is greater than the upper bounds at 10%, 5%, 2.50% and 1% and their p-value is less than 0.05% therefore it concluded that there is a significant long run relationship among the variables. Further the long run coefficients are estimated below.

**Long run coefficients**

After confirming that there is long run relationship among the variable. Table 4.6 presented the long run coefficient for the independent variables.
the long run coefficient for the R&D, education, and infrastructure & credit disbursement

<table>
<thead>
<tr>
<th>Variables</th>
<th>Coefficient</th>
<th>Standard error</th>
<th>T-ratio</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>LNR$D$</td>
<td>0.163231</td>
<td>0.130879</td>
<td>1.247195</td>
<td>0.2244</td>
</tr>
<tr>
<td>LNEDULN</td>
<td>0.637077</td>
<td>0.215234</td>
<td>2.959928</td>
<td>0.0068</td>
</tr>
<tr>
<td>LNINFRA</td>
<td>0.254569</td>
<td>0.101431</td>
<td>2.509768</td>
<td>0.0192</td>
</tr>
<tr>
<td>LNCRD</td>
<td>0.015920</td>
<td>0.065960</td>
<td>0.241366</td>
<td>0.8113</td>
</tr>
<tr>
<td>C</td>
<td>-3.206025</td>
<td>1.715029</td>
<td>-1.869370</td>
<td>0.0738</td>
</tr>
</tbody>
</table>

Above results showed that there is positive and significant long run relationship between the education and TFP. It means when primary level education increases, it leads to an increase in TFP for long run (Kendrick and Sato, 1963., Kendrick, 1973). Ali, Mushtaq et al. (2012) results also showed that there is positive and significant long run relationship. The p-value of infrastructure is also less than 0.05% it mean that there is significant long run relationship. The results are in line with the Azam, Bloom et al.(1991) and Zhang and Kumaraswamy(2001). Zhang and Kumaraswamy (2001) explained in his paper that in china agricultural productivity is highly effected by the infrastructural development in long run. Research and development has a positive but insignificant relationship in the long run, because P-value is greater than 0.05%. This means that null hypothesis is accepted and alternative hypothesis is rejected. Also, it states that R$D$ has positively affected the TFP but their insignificant relationship showed that government should improve the research and extension department of agriculture in order to achieve the long run benefits.

The result of LNCRD is positive but insignificant in long run with the dependent variable TFP. The reason behind the insignificance relationship between LNCRD and TFP are the improper utilization and discrimination in its distribution. The result of LNCRD is in line with the Ali, Mushtaq et al.(2012).

**Short run coefficients and ECM**

Table-4.7 showed the short run coefficients, this is the final step of ARDL in which short run coefficient is estimated. ECM (-1) is a term which is calculated through the long run equilibrium relationship, it is also known as the long run multiplier. The ECM (-1) term must be negative and highly significant and it must be in the range of 0 to -1. 0 implies that there is no convergence after a shock while -1 showed that there is perfect convergence (Pesaran, Shin et al., 2001).

**Error Correction Representation and short run coefficient for the variables.**
ECT(-1) = TFP - (0.6371*EDULN + 0.1632*RSD + 0.2546*TELELN + 0.0159*LNCRD - 3.2060)

The above table showed that there is a positive and significant relationship between TFP and RSD at 5%. The coefficient of short run is high as compared to the long run coefficient which showed that when the government invest more on the research and development it will increase the TFP rate. The results are in line with Nadeem, Javed et al. (2010) he explained in his results that if the government do not keep the investment consistent in research and development, then decrease in investment will lead to shocking situations in future. RSD is significant in short run but insignificant in long run and it is not a good sign. Infrastructure and education both are positive and significant in short run as well. The results are in line with Jorgenson and Griliches (1967), Fan (1997) and Ali, Mushtaq et al. (2012). The result of credit disbursement showed that it is positive but insignificant relationship with the TFP. The result of LNCRD is positive and insignificant both in short run as well as in long run.

The ECT(-1) term is negative and highly significant and the coefficient is less, therefore now it is good to explain the disequilibrium in short run which will be fixed in the long run. The coefficient of ECT(-1) term showed that the equilibrium process is quite fast. 50% of the
previous year’s disequilibrium in the TFP from the equilibrium will be adjusted in the upcoming years.

**Diagnostic test of the residuals**

For the selection of the best fitted model the following diagnostics test has been conducted.

**Breusch-Godfrey Serial Correlation LM Test**

The current study used Breusch-Godfrey (B-G) test for diagnosing the serial correlation in the error terms of the model. This test is statistically more powerful than the Durban Watson test statistic Brooks (2008). The null hypothesis of the B-G test are there is no autocorrelation, while the alternative hypothesis are there is autocorrelation.

H0: ρ1 = 0 and ρ2 = 0 and ...and ρr = 0  
H1: ρ1 ≠ 0 or ρ2 ≠ 0 or...or ρr ≠ 0

Table 4.8 showed that p value of the F-statistic is greater than 0.05 therefore the null hypothesis is accepted and alternative hypothesis is rejected. It mean that there is no autocorrelation and the correlation between the error terms with its lag value is zero. So this is a good sign for the model.

<table>
<thead>
<tr>
<th>Breusch-Godfrey Serial Correlation LM Test</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>F-statistic</td>
<td>0.593851</td>
</tr>
<tr>
<td>Prob. F(1,24)</td>
<td>0.4485</td>
</tr>
<tr>
<td>Obs*R-squared</td>
<td>0.941707</td>
</tr>
<tr>
<td>Prob. Chi-Square(1)</td>
<td>0.3318</td>
</tr>
</tbody>
</table>

**Heteroscedasticity Test: Breusch-Pagan-Godfrey**

Trevor-Breusch and Adrian-Pagan has developed the Breusch-Pagan-Godfrey test in 1979. This test has been used for the insignificance of the Heteroscedasticity in the linear regression model. Heteroscedasticity is the absence of homoscedasticity i.e. the variables of the model are not of the same spread. Null hypothesis is that there is no Heteroscedasticity while the alternative hypothesis is there is Heteroscedasticity(Brooks, 2008).

The table 4.9 result showed there is no Heteroscedasticity in the model because p-value against the Observed R-squared is greater than 0.05 it means that null hypothesis is accepted and alternative hypothesis is rejected.
Heteroscedasticity test

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>F-statistic</td>
<td>0.710581</td>
<td>0.7363</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Obs*R-squared</td>
<td>10.5225</td>
<td>0.6508</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scaled explained SS</td>
<td>5.936087</td>
<td>0.9484</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Stability test (Cumulative Sum of Recursive Residuals)

The stability test cumulative sum (CUSUM) and the cumulative sum of squares (CUSUMQ) which were introduced by the Brown, Durbin et al. (1975) has been used for finding the stability of its parameters. The test CUSUM shows if the cumulative sum goes outside the two critical lines, then the model is not free from instability. Similarly, CUSUMQ, which is based on squared recursive residuals, goes outside the critical lines, and then the model is instable. The CUSUM parameter stability tests ensure that the variables are stable during the period of study (1961-2013). Because the lines are in between the two lines which mean that there is no structural break. The overall model is stable.

![CUSUM Graph](image)

Normality Test

Jarque-Bera test has been conducted for testing the normal distribution of the error terms. Normal distribution of residuals are alternatively called as the normal distribution of the kurtosis and skewness. The null hypothesis of the jarque-bera test: the residuals are normally...
distributed in model. The alternative hypothesis: the residuals are not normally distributed in the model (Brooks 2008). Results showed that residuals are normally distributed in the model because the p-value of Jarque-Bera is greater than 0.05 therefore we fail to reject the null hypothesis.

Normality Test

<table>
<thead>
<tr>
<th>Series: Residuals</th>
<th>Sample 1 43 IF 1971-2013</th>
<th>Observations 39</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>-7.52e-15</td>
<td></td>
</tr>
<tr>
<td>Median</td>
<td>-0.017024</td>
<td></td>
</tr>
<tr>
<td>Maximum</td>
<td>0.475414</td>
<td></td>
</tr>
<tr>
<td>Minimum</td>
<td>-0.308741</td>
<td></td>
</tr>
<tr>
<td>Std. Dev.</td>
<td>0.174865</td>
<td></td>
</tr>
<tr>
<td>Skewness</td>
<td>0.712309</td>
<td></td>
</tr>
<tr>
<td>Kurtosis</td>
<td>3.745746</td>
<td></td>
</tr>
<tr>
<td>Jarque-Bera</td>
<td>4.201724</td>
<td>0.122351</td>
</tr>
</tbody>
</table>

Conclusion

The current study aim was to find the technological progress (TFP) in agriculture sector and also to check the relationship of the macro economic variables with this. The results realized those factors which effected the productivity in different decades. Increase in inputs is not only the cause of favourable production, but the main thing is to efficiently utilize those resources. TFP index showed that in 60’s when government implement strategies effectively it increased our TFP rate. The study also showed that TFP are not only increased by the efficiently utilization of inputs. There are some other factors which intervening the TFP rate. Therefore the study considered research and development, infrastructure, education and credit disbursement as a three main variables which are selected on the basis of literature review. Research and development, infrastructure and education showed positive and significant relationship but credit disbarment are positive and insignificant both in short run as well as in long with TFP.
Recommendation

The following recommendations have been forwarded on the basis of empirical results and findings of the current study:

• The government should try to improve their implementation strategies and provide the good mechanism to the farmers, in order to efficiently utilize the current resources.

• Research and development factor showed poor performance, therefore government should increase their activities by public investments and through development programs in order to achieve the long run relationship with the TFP.

• Government should focus on all the subsectors of agriculture equally, because government neglected the forest subsector after 1970 and if government will developed a productive plans for the forestation the flood rates will also be reduced and ultimately crop lands will be safe from the large destructions.

• Credit disbursement results were insignificant therefore it is suggested that small farmers should be provided with easy access to credit. Credit for mechanization in agriculture should be amplified in order to apprehend its long run impact on productivity. Administration hurdles should be eliminated in order to increase the easy access to credit by small farmers. The field officers responsible for monitoring the activities of farmers should also be trained and motivated to ensure proper utilization of resources.

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