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DECOMPOSITION OF TOTAL FACTOR PRODUCTIVITY OF CASH CROPS IN PAKISTAN: A MALMQUIST DATA ENVELOP ANALYSIS

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ABSTRACT

This paper examined the total factor productivity of cash crops in Pakistan from 1980 to 2018. It uses Malmquist productivity index by applying data envelop analysis to estimate the changes in the production frontier. The Malmquist productivity index is used to decompose total factor productivity into technical change (TECCH) & technical efficiency change (EFFCH). Technical change (TECHCH) means shifts in the frontier or innovation, while efficiency change means catching up to the frontier. The Empirical results show an increase in the productivity of the cash crop in Pakistan. The objective of the study is the decomposition of the total factor productivity of cash crops in Pakistan. Three cash crops (sugarcane, cotton, and rice) and seven inputs (arable land, irrigated land, use of electricity, use of petroleum product, education, credit facility, and machinery) have been used. The study found a 2.2% increase in total factor productivity of cash crops in Pakistan which was mainly due to technological change, and the efficiency score of cash crops in Pakistan has been decreased relative to previous years, which is 8.40% in the period's t+1, and compared to 10.44% in the period's t. The government should invest in research and extension in order to provide better seed varieties, better infrastructure, and ensure credit facilities.

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INTRODUCTION

Agriculture plays a very important role in the progress of the countries. Pakistan is an agricultural country, and this sector is the backbone of the Pakistan economy. The contribution of the agriculture sector is 18.5% of the gross domestic product and employs 38.5% of the labor force, and is also a huge source of raw material for many agro-based industries in Pakistan. Agriculture productivity growth is one of the important research topics analyzed by the development and agricultural economist to trace out the determinants and resources of the growth rate of productivity over time and to find out differences among regions and countries with regard to their growth rate of productivity. The current position of agriculture productivity and its vital role in decreasing gaps between income and poverty in Pakistan needs policies and programs which enhance total factor productivity. Therefore, such studies and research are required help to provide empirical evidence that explains the "total factor productivity" sources and determinants, which will be helpful in making policies and programs. The determinants of agricultural productivity have been well explained in economic literature for total factor productivity and partial (labour and capital). Fare et al. (1994a) decomposed growth in productivity into efficiency change and technological change. Whereby change in technical efficiency we mean the more efficient use of the current amount of inputs, whereby technological change we mean the implication of new technology of production. Over the last five decades, growth in agricultural productivity has remained an important aspect for deep study. The growth accenting approach was introduced by Solow (1957), defined the increase in total factor productivity is a part of production which could not be defined by growth in factor inputs such as land, capital and labour. Agricultural and development economists have estimated productivity and analyzed differences in productivity growth among different counties and regions. The growth in productivity is necessary to fulfill the demand of a steadily growing population. For analysis of the performance of any output system and growth process sustainability, total factor productivity is an important measure. Decomposition of total factor productivity is one of the important concepts which are used by different researchers to measure growth in agricultural output within a country and across countries. Different methods have been used by the researchers for the estimation of total factor productivity. There are different methods for measurement and evaluation of total factor productivity, such as parametric (Stochastic frontier analysis) and nonparametric (Malmquist productivity Index), etc. Malmquist Productivity Index. This study used Malmquist productivity Index using data envelop analysis, a nonparametric technique. This paper analyzed total factor productivity by decomposing it into technical efficiency change and technological change by applying the Malmquist productivity index, using data envelop analysis from 1980 to 2018. Different researchers worked on and conducted studies to analyze the agricultural productivity of Pakistan (Parikh and Shah, 1994; Hussain and Ishfaq, 1997; Khan et al., 2003; Iqbal et al., 2002; Ahmad, 2001; Mushtaq and Dawson, 2003; Ali and Iqbal, 2004; Ali and Iqbal, 2005; Kiani et al., 2008; Fatima and Yasmin, 2016). However, these studies used old data sets or focused on partial studies. The aim of this study was a significant and original contribution to on-hand literature on total factor productivity with the help of resources such as a change in efficiency and change in technology to check the impact of different variables including conventional and non-conventional. This paper examined total factor productivity instead of partial productivity (capital and labour). For the analysis of Pakistan agricultural productivity growth, the study considered three cash crops such as rice, sugarcane and cotton, and different inputs (conventional and non- conventional) such as arable land, irrigated land, use of electricity, and oil in the agriculture sector, education of the farmers, credit availability, machinery (no of tractors) and labour participation in agriculture sector production.

Cash Crops

There are three cash crops such as rice, cotton and sugarcane. The cropped area of different crops has been changed over the time. The rice and wheat crops account for 46% of the cropped area presently and since 1960 the share of these crops has been increased. Other cereal crops have been displaced by these crops. The area of sugarcane and cotton has been also increased over time. Since the early 1960s, the average growth rate in the physical production of the four major crops has been fairly high. The area, production, and yields of the cash have been increased over time, but the growth in the areas under sugarcane has been the highest. The area, production, and yields of the cash crops have been shown in Table 1.

Table 1. Area, production, and yield of cash crops.

Year	Crop	Area	Production	Yield
1980-81	Cotton	2108.5	4201.0	339.0
2017-18		2699	11935	752
1980-81	Rice	1933.3	3123.2	1616.0
2017-18		2899	7442	2567
1980-81	Sugarcane	824.7	32359.4	39.2
2017-18		1313	81102	61768

Note: Area (000 H), production (000 Tones) except cotton (000 bales), yield (kg/h) (Source: Pakistan Bureau of Statistics).

METHODOLOGY

Sample and data

The study was conducted on the total factor productivity of the cash crops (sugarcane, cotton, and rice) of Pakistan from 1980-81 to 2017-18. The study used secondary data collected from different publications of the Pakistan bureau of statistics.

Variables of the Study

The study used seven inputs such as arable land, irrigated land, use of electricity, use of petroleum products, education, credit facility, and machinery (no. of tractors).

For analysis of the performance of any output system and growth process sustainability, total factor productivity is an important measure. Decomposition of total factor productivity is one of the important concepts which are used by different researchers to measure growth in agricultural output within countries and across countries. Different methods have been used by the researchers for the estimation of total factor productivity. There are different methods for measurement and evaluation of total factor productivity, such as parametric (stochastic frontier analysis) and nonparametric (Malmquist productivity Index). Maximum likelihood estimation of stochastic frontier production is used by stochastic frontier analysis, which is a parametric technique. The non-negative error term is used for the estimation of technical efficiency SFA is more, and many hypotheses can be tested. Battese and Coelli's (1995) model has been used in most recent research, using stochastic frontier analysis. Battese and Coelli's (1992) stochastic frontier production model is given below which is used for efficiency and technological change.

$$\ln q_{it} = x_{it} + v_{it} - u_{it} \quad (1)$$

$i = 1,\ldots,N$ and $t = 1,\ldots,T$, where N stands for provinces and T stands for the time period.

Stochastic frontier production function model in Cobb-Douglas form:

$$\ln q_{it} = B_0 + B_1 \ln x_{it} + v_{it} - u_{it} \quad (2)$$

$$\text{Or } q_{it} = \exp(B_0 + B_1 \ln x_{it}) * \exp(v_{it}) * \exp(-u_{it}) \quad (3)$$

Where, q_{it} is province i output at time period t, x_{it} is inputs quantity of province i during time period t, B stands for parameters which were calculated.

$\exp(B_0 + B_1 \ln x_{it})$ are deterministic factors.

$\exp(v_{it})$ = statistical noise or random noises, v_{it} maybe minus or plus, and assumed to be normally distributed and independent of u_{it}.

$u_{it} = (u_i \exp(-\eta(t - T))$ u_i stand for non-minus random noises and truncated normal distribution. $\exp(-u_{it})$ stand for "technical inefficiency", Ƞ stands for parameter and shows improvement of technical efficiency over time. If $\eta = 0$ stands for the efficient time-invariant model, otherwise inefficient time-variant model. For estimation of technological change, a variable of time trend is added in equations (2) & (3). The average technological change can be measured by estimating the variable of the time trend coefficient.

This study has been conducted on the decomposition of total factor productivity of cash crops in Pakistan from 1980 to 2018. The concept of productivity in the production procedure is used to take into accent efficiency change and technical change when inputs are transformed into outputs (Chambers, 1988; Coelli et al., 1998). Farrell (1957) defined two types of production efficiency such as technical efficiency, which take into account a firm's ability to achieve maximum output from available inputs, and another is allocative efficiency, where marginal revenue product is compared with the marginal cost of inputs to measure firm's ability to maximize its profit. Usually, with given prices and technology, for estimation of technical and allocative efficiency, stochastic frontier analysis is used; however, the specification of production technology is required by this econometric approach. But Data Envelopment Analysis is a mathematical programming approach that is used to estimate technical efficiency by combining the production of the firm to the best production frontier (Seiford and Thrall, 1990). There are two types of productivity such as total and partial or average factor productivity, where the average product is a rate of output to a specific input. Let Y is output and x_i be any individual input, then the average product is;

$$AP = \frac{Y}{Xi} \qquad (4)$$

It estimates the role of one specific input to technical change and ignores the other inputs' effects, while total factor productivity is the average product of all inputs factors or a ratio of output to the index of inputs. Thus TFP is;

$$TFP = \frac{Y}{\sum \alpha i Xi} \qquad (5)$$

Where input x_i weight is αi. By using restrictions on the parameters, total factor productivity is calculated with the help of aggregate production or cost function. A different index is used for calculation of TFP such as Laspeyers, Paasche, Fisher, or Törnqvist-Theil. Index restrictions are used on production technology in term of weights on inputs and outputs, therefore, indices are the ratio of an aggregate output index to an index of total inputs used. Törnqvist-Theil index is admired form in the past for calculating TFP but it needs price information and uses cost/revenue shares as weights to aggregate inputs and outputs. Malmquist productivity gained popularity because;

1. It is calculated from the distance function and requires data of quantities.
2. It allows for inefficient performance and does not assume the functional form of the production technology.
3. It does not require the assumption of the producer's optimizing behavior.
4. It is a nonparametric technique and does not require econometric estimation.

Given the production technology S^t for each time period t= 1, 2…., T shows the conversion of inputs, $X^t \in R^N+$ into outputs, $Y^t \in R^M +$.

$$S^t=\{(X^t, Y^t): X^t\ can\ produce\ Y^t\} \qquad (6)$$

Where to define important output distance functions S^t is assumed to fulfill the mandatory axioms. Fare et al. (1994b) defined the output distance function in time period t as;

$$D_0^t(x^t, y^t) = \inf[\theta : (x^t, y^t/\theta) \in S^t]$$
$$= [\sup\{\theta: (x^t, \theta y^t) \in S^t\}]^{-1} \qquad (7)$$

Therefore distances are basically opposite of the maximal proportional increase of the output vector Y^t, given inputs X^t and equal to the reciprocal of Farrell's (1957) efficiency of output measure, which estimates total factor productivity "catching up" of observation to the best frontier is defined high or low productivity degree. Moreover, $D^t_0(x^t, y^t) = 1$ when (x^t, y^t) is on the frontier or boundary of technology, which occurs only if there is technically efficient production. If $D^t_0(x^t, y^t) < 1$, it means that production at time period t is inside the frontier of the boundary of technology and technically inefficient production. Therefore degree of technical inefficiency is measured by distance function. In time period t+1, the output distance function can be defined as (4) by replacing t+1 with t, thus in two time periods the output distance function is defined as;

$$D_0^t(x^{t+1}, y^{t+1}) = \text{info}[\theta : (x^{t+1}, y^{t+1}/\theta) \in S^{t+1}]$$
$$\theta > 1 \qquad (8)$$

Therefore it is a mixed index that estimates the maximal relative change in outputs y^{t+1} given inputs x^{t+1} under the technology t, which is explained in Figure 1. In the figure production (x^{t+1}, y^{t+1}) lies above the feasible production in time period t, shows technical change. Figure 1 shows the analysis of output distance function (Fare et al., 1994b). The figure shows distance function of the value (x^{t+1}, y^{t+1}) linked to the technology in period t is OD/OE, that is greater than one. In the same way we can explain the mixed distance function, $D_0^{t+1}(x^{t+1}, y^{t+1})$, which estimates relative change in output y^t, given inputs x^t, with respect to the technology at time period t+1.

Caves at el. (1982) proposed this method, based on distance function and introduced by Malmquist in 1953. Productivity growth was decomposed into two components (technical changes and efficiency changes) over time by Fare et al. (1994b). They used output distance function and computed changes in productivity with the help of geometric mean of two MP indexes.

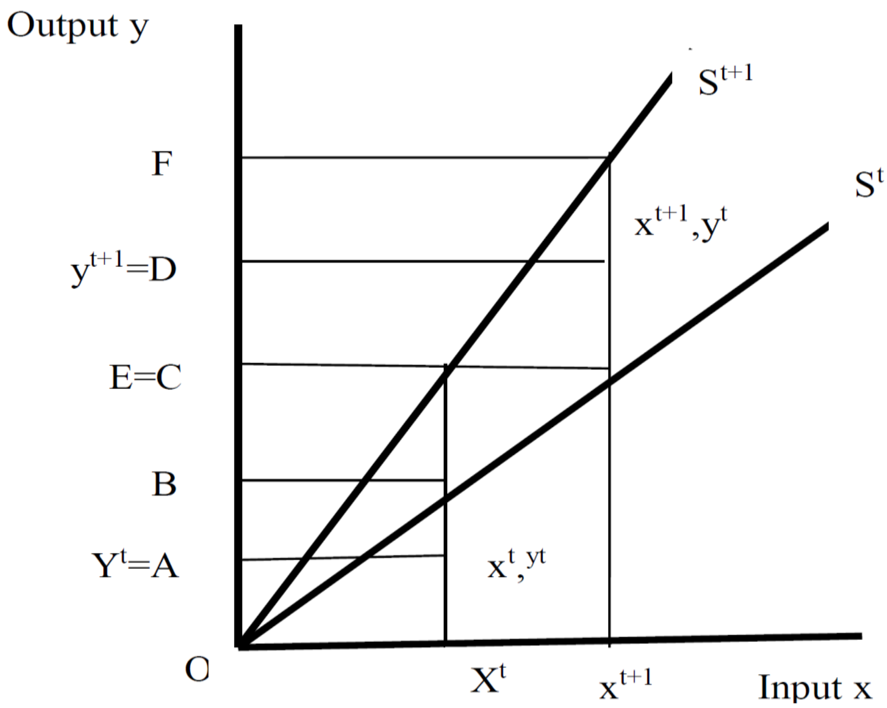

Figure 1. Output distance function and TFP (MPI).

Malmquist Productivity Index is expressed by Distance function (E) in equation (9) and equation (10) via the observation in time period t and t+1.

$$MPI_I^t = \frac{E_I^t(x^{t+1},y^{t+1})}{E_I^t(x^t,y^t)} \quad (9)$$

$$MPI_I^{t+1} = \frac{E_I^{t+1}(x^{t+1},y^{t+1})}{E_I^{t+1}(x^t,y^t)} \quad (10)$$

Where I shows point of reference of MPI.
Equation 8 is derived by 2 geometric mean of Malmquist productivity indices in equation 9 and 10.

$$MPI_I^G = (MPI_I^t . MPI_I^{t+1})^{1/2} = \left[\left(\frac{E_I^t(x^{t+1},y^{t+1})}{E_I^t(x^t,y^t)}\right).\left(\frac{E_I^{t+1}(x^{t+1},y^{t+1})}{E_I^{t+1}(x^t,y^t)}\right)\right]^{1/2} \quad (11)$$

The geometric mean of MPI is decomposed into input-oriented efficiency change (EC) and input oriented technical change (TC) given in the equation 9.

$$MPI_I^G = (EC_I).(TC_I^G) = \left(\frac{E_I^{t+1}(x^{t+1},y^{t+1})}{E_I^t(x^t,y^t)}\right).\left[\left(\frac{E_I^t(x^t,y^t)}{E_I^{t+1}(x^t,y^t)}\right).\left(\frac{E_I^{t+1}(x^t,y^t)}{E_I^t(x^t,y^t)}\right).\left(\frac{E_I^t(x^{t+1},y^{t+1})}{E_I^{t+1}(x^{t+1},y^{t+1})}\right)\right]^{1/2} \quad (12)$$

The first term represents efficiency change and second term represents technological change. The left side of the equation 9 measure efficiency change under constant return to scale and its estimates degree of catching up to the best frontier between two time periods t and t+1 for each observation, whereas right side of equation shows the technical change index which revels shift in the frontier due to innovations between two time periods x^t, x^{t+1}. Therefore Malmquist total factor productivity index is a combination of efficiency change and technological change as shown below.

TFPCH= TEFCH× TECHCH

It means that the decomposition of MPI tells us about changes in total factor productivity due to technical efficiency change and technological change. Fare et al. (1994a, b) explained that if MPI is greater than one means increase in productivity and MPI less than one reveals decrease in productivity. Further improvement in any two component of MPI is linked with the value >1 and decrease linked with <1.

RESULTS AND DISCUSSION

Data Analysis of Malmquist Productivity Index

The value of Malmquist conductivity index or any of its component either efficiency change or technological change is less than one shows decrease in performance, while a value greater than one reveals an improvement or increase in the performance or productivity and equal to one means no change in productivity. Total factor productivity growth has been shown variation during the period 1981-2018 which is shown in Table 2. In the Table, out of 37 Malmquist productivity index, 20 years show values greater than one. Technological change has been main source of total factor productivity growth during the period 1981-2018. The values greater than one reveals upward shifting of the production frontier at national level. The lowest value of the total factor productivity change is 0.482 during the year 1997-98, which means that total factor productivity has been decreased by 51.8%(1-0.482= 0.518*100=51.8%). The highest value of the total factor productivity is 1.794 during the period 1998-99, which means that total factor productivity has been increased by 79.4% (1.794-1= .794*100=79.4%). The mean of total factor productivity for the whole duration is 1.022 which means that on the average total factor productivity of the cash crops in Pakistan has been increased by 2.2% (1.022-1=0.22*100=2.2%).

In Table 2, the technical efficiency change values are equal to one for the whole duration, showing that it is on the best frontier. Therefore it is clear from the results of the Malmquist productivity summary that change in total factor productivity is mainly due to technical innovation rather than the improvement in the technical efficiency. Table 2 also shows a distance summary of Pakistan's cash crops. Recall it is explained that if the value of TFP is greater than one, it shows an increase in productivity. All the values during the whole period are greater than one except 2010-11, which value is 0.977, less than one, and shows a decrease in the productivity. But the efficiency change compound growth rate of cash crops in Pakistan has been deteriorated relative to previous years, with 8.40% in the period (t+1), compared to 10.44% in the period (t).

Table 2. Malmquist index summary and distance summary of Pakistan's cash crops.

Years	TEFCH	TCHCH	TFPCH	Years	T	T+1
1981-82	1.000	1.110	1.110	1981-82	1.406	1.291
1982-83	1.000	0.954	0.954	1982-83	1.176	2.052
1983-84	1.000	0.717	0.717	1983-84	1.055	1.298
1984-85	1.000	1.261	1.261	1984-85	2.065	1.279
1985-86	1.000	1.034	1.034	1985-86	1.368	1.153
1986-87	1.000	1.075	1.075	1986-87	1.333	1.479
1987-88	1.000	0.898	0.898	1987-88	1.193	1.065
1988-89	1.000	1.087	1.087	1988-89	1.259	1.155
1989-90	1.000	1.007	1.007	1989-90	1.171	1.466
1990-91	1.000	1.171	1.171	1990-91	2.011	1.094
1991-92	1.000	1.333	1.333	1991-92	1.944	2.237
1992-93	1.000	0.659	0.659	1992-93	1.016	1.205
1993-94	1.000	1.085	1.085	1993-94	1.419	2.080
1994-95	1.000	0.771	0.771	1994-95	1.238	1.117
1995-96	1.000	1.134	1.134	1995-96	1.436	1.215
1996-97	1.000	1.301	1.301	1996-97	2.058	5.966
1997-98	1.000	0.482	0.482	1997-98	1.388	1.894
1998-99	1.000	1.794	1.794	1998-99	6.092	1.481
1999-00	1.000	0.980	0.980	1999-00	1.421	1.164
2000-01	1.000	0.971	0.971	2000-01	1.098	1.409
2001-02	1.000	1.020	1.020	2001-02	1.464	1.741
2002-03	1.000	0.872	0.872	2002-03	1.324	1.174
2003-04	1.000	0.994	0.994	2003-04	1.161	1.225
2004-05	1.000	1.224	1.224	2004-05	1.834	2.297
2005-06	1.000	0.913	0.913	2005-06	1.915	1.211
2006-07	1.000	1.011	1.011	2006-07	1.237	1.241
2007-08	1.000	0.985	0.985	2007-08	1.204	1.351
2008-09	1.000	1.287	1.287	2008-09	2.239	1.529
2009-10	1.000	0.927	0.927	2009-10	1.313	1.469
2010-11	1.000	1.044	1.044	2010-11	1.602	0.977
2011-12	1.000	1.509	1.509	2011-12	2.226	1.519
2012-13	1.000	0.884	0.884	2012-13	1.188	1.495
2013-14	1.000	1.067	1.067	2013-14	1.701	1.444
2014-15	1.000	0.974	0.974	2014-15	1.370	1.494
2015-16	1.000	1.338	1.338	2015-16	2.672	1.535
2016-17	1.000	0.927	0.927	2016-17	1.320	1.225
2017-18	1.000	0.959	0.959	2017-18	1.126	NI*
Mean	1.000	1.022	1.022	ACGR*	10.40 %	8.44%

ACGR*= Average compound growth rate; NI*= not included; Source: Results from Deap 2.1 Estimates.

CONCLUSIONS AND RECOMMENDATIONS

There was no need for price information; only data of inputs and outputs were used by this approach. Decomposition tells us how much change in total factor productivity in Pakistan is achieved due to efficiency change and technological change. The study found that the change in total factor productivity of cash crops in Pakistan is due to technological change, whose mean value is 1.022. Already it is defined that if the MPI value is greater than one, it means an increase in productivity, less than one shows a decrease in productivity, and equal to one shows no change in the productivity. Therefore the increase in total factor productivity of cash crops in Pakistan during the period 1981-82 to 2017-18 is 2.2%, mainly to technological change, while the efficiency value is one throughout the whole duration and reveals that it is on the best frontier or boundary. The efficiency score of cash crops in Pakistan has been decreased relative to previous years, which is 8.40 in period's t+1, and compared to 10.44% in the period's t**.**

Therefore it is suggested that government should take into account the factors which are helpful in improving productivity in a greater ratio. As the results show that technological change has a major role in increasing productivity, so the government should invest in research and extension. The government should enhance the public sector agricultural investment in research and development with the other countries in the region. The government should provide a safe environment for foreign and private investment in agriculture R&D. it should improve the coordination in research and technology dissemination, employ qualified and trained human resources in research, focus on demand drive research, and improve research infrastructure. The cost of production should be minimized by providing subsidies for inputs such as electricity, petroleum products, fertilizer, seeds, pesticides, farm machinery, and loan facilities. Better infrastructure such as irrigation and roads should be provided to increase productivity.

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