The Pharma Innovation Journal 2019; 8(4): 711-717

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277- 7695
ISSN (P): 2349-8242
NAAS Rating: 5.03
TPI 2019; 8(4): 711-717

www.thepharmajournal.com
Received: 10-02-2019
Accepted: 12-03-2019

Huma Sehar
VAEO, Department, Agriculture
Jammu and Kashmir, India

Jyoti Kachroo
Department, Agriculture
Jammu and Kashmir, India

Dileep Kachroo
Department, Agriculture
Jammu and Kashmir, India

Mudasir Iqbal
Department, Agriculture
Jammu and Kashmir, India

Correspondence
Huma Sehar
VAEO, Department, Agriculture
Jammu and Kashmir, India

Total factor productivity of rice-wheat system in Jammu: A stochastic approach

Huma Sehar, Jyoti Kachroo, Dileep Kachroo and Mudasir Iqbal

Abstract
A study was undertaken to analyze the Total Factor Productivity (TFP) of rice-wheat system at Farming System Research Center Jammu on the basis of time series data on inputs and output for a period of 25 years (1986-97 to 2010-11). The results from the table indicated that for most of the years during last 25years exhibited TFP less than one. Technical regression was found through the periods and also there were dwelling technologies. Most of the period observed efficiency change and technical change less than one were as impact of efficiency change was greater than technological changes. Except for treatment T_5 and T_6 during period V where they observed marginal increase, all other treatments observed decline in TFP during entire period of study

Keywords: Total factor productivity, stochastic frontier production function, decomposition of TFP

Introduction

Agricultural policy in India across decades has been focusing on self-sufficiency and self-reliance in foodgrain production. Considerable progress has been made on this front due to which foodgrain production rose from 52 million tonnes in 1951-52 to 244.78 million tonnes in 2010-11 growing at an annual average rate of more than 2.4 per cent (Anonymous, 2011) [5]. Although all major crops have witnessed a significant growth in production, still the recent trends in Indian agriculture presents a dismal picture. The growth rate in production of all principal crops is far behind population growth rate, the net per capita availability of foodgrains in the country has come down from 471 gram per capita per day during 1990s to 456 gram per capita per day during 2000 (Anonymous, 2004) [3]. While demand for agriculture and food products is rising at a high rate, the resource base for production is shrinking. This implies that more output needs to be produced per unit bundle of resources which requires a paradigm shift in productivity from a single resource (partial productivity) to productivity of entire set of resources used in production i.e. Total Factor Productivity (TFP). Recent years have seen a surge in both theoretical and empirical studies on total factor productivity (TFP) in order to frame agricultural policies which are echoed in the debates on technology fatigue and policy fatigue (Anonymous, 2010) [4]. Consequently in future it will be increasingly difficult to expand convention factors of production such as agricultural land and labor without growth in TFP.

In the period during which TFP witnessed an upward (1960-95) and downward trend (1996-2010), there was and is still at many places an indiscriminate exploitation of natural resources in the intensively cultivated areas which has raised concern about the long term sustainability of agricultural production system and environment. Unscientific use of agricultural inputs (either natural or manmade) and inefficient farming systems are resulting in aggravation of many environmental disorders e.g. soil erosion, loss of diversity of flora and fauna, contamination of ground water, depletion of ozone layer etc (Chavan, 2011) [11]. Therefore, sustainable development demands an integrated and interactive approach that allows for the understanding of the complex relationship between society and nature, simultaneously respecting human rights and assuming that environment is a vital dimension of the future of the human kind (Lourenco,2001).

In recent years, national and international research organizations have responded to the increasing importance of sustainability in agricultural development for this reason Indian Council of Agricultural Research harness science to ensure sustained physical, economic, and ecological access to food and livelihood security to all through generation, assessment, refinement, and adoption of appropriate technologies.

All these features of sustainable agriculture should be considered as a package, and no single feature should predominate over the others (Anonymous, 1999) [2]. Thus, on one hand TFP has gained scope worldwide and on the other hand it has raised concern of economic, social and ecological sustainability. As a result, it is necessary that sustainability and TFP indices i.e output/input ratios should be examined together with many soil health factors, and atmospheric externalities (Barnett *et al*, 1995) [6].

Materials and Methods

Trends and determinants of total factor productivity

The data collected from FSRC included time series data on output i.e. production and price and input data on human labour, seeds, fertilizers, herbicide and irrigation, for a period of 25 years (1986-87 to 2010-11). Various long term experiments on rice wheat system are being carried out at FSRC i.e. Treatment 1 (T_1) no fertilizer and no FYM was used, Treatment 2 (T_2) 50 inorganic fertilizers and no organic fertilizer, Treatment 3 (T_3) same as T_2, Treatment 4 (T_4) 75 per cent inorganic fertilizer and no organic fertilizer, Treatment 5(T_5) 100 per cent inorganic fertilizer, Treatment 6 (T_6) 50 per cent inorganic fertilizer and 50 per cent FYM, Treatment 7 (T_7) 75 per cent inorganic fertilizer and 25 per cent FYM, Treatment 8 (T_8) 50 per cent inorganic fertilizer and 50 per cent paddy straw, Treatment 9 (T_9) 50 per cent inorganic fertilizer and 50 per cent paddy straw, Treatment 10 (T_{10}) 50 per cent inorganic fertilizer and 50 per cent green manure, Treatment 11 (T_{11}) 75 per cent inorganic fertilizer and 25 per cent green manure and Treatment 12 (T_{12}) farmers' practice. Out of which four treatments were considered for the present study which included Treatment 1(T_1), Treatment 5 (T_5), Treatment 6 (T_6) and lastly Treatment 12 (T_{12}). These four treatments were of economic importance as fertilizers are one of the major limiting factor in agricultural production process and to maintain long term sustainability of land it is necessary that soil should be treated with organic manure. FYM is considered as an important nutrient supplier to the soil compared to other organic manure, thus these four treatments were best suited for the study.

TFP can be calculated by estimating aggregate production function or cost function using econometric parameters. It can also be measured by using indices such as Tornqvist- Theil, Paasche, Laspeyers or Fisher models. However, these approaches impose restriction on production technology by influencing inputs and outputs. Therefore, Frontiers such as Data Envelopment Analysis Programme (DEAP) and Stochastic Frontier Analysis (SFA) were used to measure productivity change, and to decompose this productivity change into technical progress and efficiency change. which involves mathematical programming and econometric methods respectively. The study covered a period of 25 years (1986-87 to 2010-11) for working out the growth rates of area, production and yield of major crops, the time period had been divided into following four different periods as:

Period I (1986-87 to 1990-91)
Period II (1991-92 to 1995-96)
Period III (1996-97 to 2000-01)
Period IV (2001-02 to 2005-06)
Period V (2006-07 to 2010-11) and
Overall Period (1986-87 to 2010-11)

Malmquist TFP index

Compared to other methods Malmquist index approach has four advantages (Fare *et al* 1994$_b$) [13]: First, since it is calculated from distance functions, it only requires data on quantities and thus less data demanding than Tornqvist- Theil index. Second, no assumption regarding optimisation behaviour of producer is necessary. Third, it allows for decomposition of TFP into efficiency change and technical change. Fourth, since it is non-parametric index it does not require econometric estimations like Tornqvist- Theil index. Thus Malmquist TFP index was used to measure TFP change and to decompose TFP change into efficiency change and technical change.

The Malmquist TFP index was first introduced by Caves *et al* (1982) [10]. They defined the TFP index using Malmquist input and output distance functions, and thus the resulting index came to be known as the Malmquist TFP index. Let the production technology S^t for each time period t = 1, 2, 3,T denotes the transformation of inputs,

$x^t \in R^N_{++}$ into outputs. $Y^t \in R^M_{++}$. S^t=(x^t, ^{yt}): $\mathbf{x^t}$ can produce $\mathbf{y^t}$}

Where S^t is assumed to satisfy required axiom to define the meaningful output distance function (Fare *et al*$_b$ 1994) in time period 't' is defined as:

$$D^t_o(x^t, y^t) = \inf\{\theta: (x^t, y^{t/}\theta) \in St\} = (\sup\{\theta: (x^t, y^{t/}\theta) \in St\})^{-1}$$

Distance function is defined as the inverse of the maximum proportional increase in the output vector y^t given the set of inputs x^t and production technology S^t. The distance so computed is equivalent to the reciprocal of Farrell's (1957) measure of technical efficiency. The superscript t associated with D refers to which period's production frontier is used as reference technology.

$$M^t = \frac{D_o^{\ t}\ (x^{t+1}, y^{t+1})}{D_o^{\ t}(x^t, y^t)}$$

i.e., they define their productivity index as the ratio of two output distance functions taking technology at time *t* as the reference technology. Instead of using period t's technology as the reference technology it is possible to construct output distance functions based on period (t+1)'s technology and thus another Malmquist productivity index can be laid down as:

$$M^{t+1} = \frac{D_o^{\ t+1}\ (x^{t+1}, y^{t+1})}{D_o^{\ t+1}(x^t, y^t)}$$

Fare *et al* (1994$_a$) [13] attempt to remove the arbitrariness in the choice of benchmark technology by specifying their Malmquist productivity change index as the geometric mean of the two-period indices, that is,

$$m_o\left(Y^{t+1}, X^{t+1}, Y^t, X^t\right) = \left(\frac{d_o^t\left(x^{t+1}, y^{t+1}\right)}{d_o^t\left(x^t, y^t\right)}\frac{d_o^{t+1}\left(x^{t+1}, y^{t+1}\right)}{d_o^t\left(x^t, y^t\right)}\right)^{1/2}$$

This represents the productivity of production point (x^{t+1}, y^{t+1}) relative to the production point (x^t, y^t). A value of $m_o > 1$ will indicate the positive TFP growth from period't' to period't+1' while the value <1 will indicate negative TFP. The index is, in fact, the geometric mean of two TFP indices, one uses period t technology and the other t+1. Using simple arithmetic manipulation, the equation (5) can be written as the product of two distinct components- technical change and efficiency change (Färe *et al* (1994).

$$M_o(x^{t+1}, y^{t+1}, x^t, y^t) = \frac{D_o^{t+1}(x^{t+1}, y^{t+1})}{D_o^t(x^t, y^t)}\left[\left(\frac{D_o^t(x^{t+1}, y^{t+1})}{D_o^{t+1}(x^{t+1}, y^{t+1})}\right)\left(\frac{D_o^t(x^t, y^t)}{D_o^{t+1}(x^t, y^t)}\right)\right]^{\frac{1}{2}}$$

Where

$$\text{Efficiency change} = \frac{D_o^{t+1}(x^{t+1}, y^{t+1})}{D_o^t(x^t, y^t)}$$

$$\text{Technical change} = \left[\left(\frac{D_o^t(x^{t+1}, y^{t+1})}{D_o^{t+1}(x^{t+1}, y^{t+1})}\right)\left(\frac{D_o^t(x^t, y^t)}{D_o^{t+1}(x^t, y^t)}\right)\right]$$

To calculate equation, I we must calculate the four component distance functions, which will involve four Linear Programming problems

$[D_o^t(xt, yt)]^{-1} = \max_{\theta, \lambda} \theta- \theta y^t, + Y^t \lambda \geq 0,$
$0,$

$[D_o^{t+1}(x^{t+1}, yt^{+1})]^{-1} = \max_{\theta, \lambda} \theta- \theta y^{t+1}, + Y^{t+1} \lambda \geq 0$
$x^{t+1} - X^{t+1}\lambda \geq 0, \lambda \geq 0$

$[D_o^t(x^{t+1}, yt^{+1})]^{-1} = \max_{\theta, \lambda} \theta- \theta y^{t+1} + Y^t \lambda \geq 0$
$x^{t+1} - X^t\lambda \geq 0, \lambda \geq 0,$

$[D_o^{t+1}(x^t, y^t)]^{-1} = \max_{\theta, \lambda} \theta- \theta y^t + Y^{t+1} \lambda \geq 0$

3.2.3.2 Stochastic frontier production function

Stochastic Frontier model was pioneered by Aigner *et al.* (1977) and Meeusen and van den Broeck (1977) [16] and extended by Pitt and Lee (1981) [17], Schmidt and Sickles (1984) [18], and Battese and Coelli (1992) [8] Battese and Coelli (1995) [9] to allow for panel data estimation, in which technical efficiency and technological progress vary over time and across production units. In this section, however, we describe the methodology used in the efficiency literature for estimating stochastic frontier production. In line with Bauer (1990) [7] and Kumbhakar *et al.* (1991) [15], we begin with a stochastic frontier model which was used to calculate function of inputs used in production on the output of both the crops (rice and wheat). Stochastic Frontier model can be estimated with panel data, in which inefficiency effects can be expressed as a specific function of explanatory variables:

$$y_{i,t} = f(x_{i,t}, t, \beta)\exp(v_{i,t} - u_{i,t})$$

where

$y_{i;t}$ denotes the output produced by industry i in year t,
$x_{i;t}$ is the corresponding matrix of explanatory variables
β is a vector of parameters to be estimated.
$v_{i;t}$'s are random errors assumed to be independent and identically distributed with mean zero and variance.
$u_{i;t}$ are non-negative random variables associated with technical inefficiency of production, which are assumed to be independently distributed.

$$TE_{i,t} = E(\exp)(-u_{i,t,})/-v_{i,t} - u_{i,t})$$

This can be used to compute the efficiency change components by observing that
$TE_{it} = d^t_o(x_{it}, y_{it})$ and $TE_{i,t+1} = d^{i,t+1}_o(x_{i,t+1}, y_{i,t+1})$ the efficiency change (EC) is
$EC = TE_{it} / TE_{i,t+1}$

An index of technological change between the two adjacent periods t and t+1 for the ith region can be directly calculated from the estimated parameters of the Stochastic Production Frontier. This is done by simply evaluating the partial derivatives of the production function with respect to time at x_{it} and $x_{i,t+1}$. If the technical change is non-neutral, the technical change may vary for different input vectors. Following Collie *et al* (1998), the technical change index is

$$TC_{it} = \left\{((1+\frac{\partial f(x_{it}, t+1, \alpha)}{\partial t+1}) \times (1+\frac{\partial f(x_{it}, t, \alpha)}{\partial t})\right\}^{1/2}$$

$$\ln y_{i,t} = \beta_0 + \beta_t t + \frac{1}{2}\beta_{tt} t^2 + \sum_j \beta_j \ln x_{j,i,t} + \sum_j \beta_{t,j} t \ln x_{i,j,t} + \frac{1}{2}\sum_j\sum_k \beta_{j,k} \ln x_{j,i,t} \ln x_{k,i,t} + v_{i,t} - u_{i,t}\, j,k = L,K$$

The Stochastic Frontier Production is defined by equation (5), and the technical inefficiency effects, specified by equation (2), can be jointly estimated by the Maximum-Likelihood Estimation (MLE) using the software such as FRONTIER, LIMDEP. In this research, however, we have employed Frontier 4.1.

Results and Discussion

Total Factor Productivity

Table 1 presented changes in Total Factor Productivity of different treatments of rice-wheat system and revealed that during period I, efficiency changes in all four treatments were greater than one (1.002). Technical change was less than one (0.984) for T_1, T_5 and T_{12} and 0.985 for T_6. The Total Factor Productivity (TFP) changes were 1.029, 0.986, 0.947 and 0.986 for T_1, T_5, T_6 and T_{12}, respectively. During period II, efficiency changes showed a marginal decrease and was observed to be 1.001 for all four treatments. Technical changes were 0.985 for T_1 and T_5, 0.979 for T_6 and 0.984 for T_{12} and TFP changes were observed to be 0.986 for T_1 and T_5, 0.980 for T_6 and 0.985 for T_{12}. Period III recorded efficiency change less than one with value 0.995 for all four treatments, technical change was found to be 0.988 for T_1, T_5 and T_6 and 0.990 for T_{12}. TFP changes were recorded to be 0.983 for T_1, T_5 and T_6, where as 0.985 for T_{12}.
The table further revealed that during period IV, there was a marginal increase in efficiency change with value 0.996 for all the treatments, technical change was recorded to be 0.993 for T_1 and T_5, 0.990 for T_6 and 0.986 for T_{12} while as TFP change was recorded as 0.989 for and T_5, 0.996 for T_6 and 0.982 for T_{12}. Period V observed efficiency change as 0.997 for T_1, T_6 and T_{12} and 0.996 for T_5, technical change was found to be 1.005 for T_1 and T_6, 0.986 for T_5 and 1.002 for T_{12} where as, TFP change was observed to be 1.002 for T_1 and T_6, 0.982 for T_5 and 1.000 for T_{12}. The overall period (1986-87 to 2010-11), recorded efficiency changes of 0.999 for all four treatments, technical change was found to be 0.989 for T_1, 0.986 for T_5, 0.982 for T_6 and 0.985 for T_{12} where as TFP change was 0.988 for T_1, 0.985 for T_5, 0.981 for T_6 and 0.984

for T_{12}. During the period V for T_5 and T_6, TFP was also observed to be greater than one indicated productivity gains by technological innovations which outweigh the impact of efficiency change and hence these two treatments reported highest productivity improvement.

OLS and MLE

The stochastic frontier estimates of different treatments of rice-wheat system (Table 2) revealed that the OLS estimates for human labour was positively significant for T_1 while as negatively significant coefficients for T_5, T_6 and T_{12} significant at 5 per cent, 1 per cent and at 10 per cent level of significance, respectively. Seeds had negative coefficient significant at 1 per cent level of significance for T_1 and T_{12} and positively significant coefficients for T_5 and T_6, significant at 1 per cent and 5 per cent level of significance, respectively. In case of herbicide all treatments had negatively significant coefficient whereas urea, had positively significant coefficients. The coefficient for phosphorus were negative for T_5, and T_{12} significant at 5 per cent level of significance whereas T_6 had positively significant coefficient at 1 per cent level of significance. Potash was having negatively significant coefficient for T_5 significant at 10 per cent level of significance and positive coefficient significant at 1 per cent level of significance for T_6. The coefficient for FYM and paddy straw had positively significant coefficients for T_6 and T_1, respectively. Likewise, coefficient for irrigation were positively significant for T_1 and T_5 at 1 per cent and at 5 per cent level of significance were as negatively significant for T_6 and T_{12} at 5 per cent and 1 per cent level of significance, respectively.

As far as machine labour was concerned, positively significant coefficients were observed for T_5, T_6 and $T_{12,}$ significant at 1 per cent, 5 per cent and 1 per cent level of significance, respectively, while as negatively significant for T_1 significant at 10 per cent level of significance. Miscellaneous charges had positively significant coefficient for T_1 and T_5 while as negatively significant coefficient for T_6, and T_{12}. The coefficient for σ^2 positively significant with the value of 0.008 significant at 1 per cent level of significance, 0.004 significant at 5 per cent level of significance, 0.003 significant at 5 per cent level of significance and 0.008 significant at 1 per cent level of significance for $T_{1,}T_5$, T_6 and T_{12}, respectively while as the coefficients of likelihood function were 51.810, 71.175, 74.621 and 54.662, respectively.

Likewise, the MLE coefficients for human labour was positive for T_1, significant at 1 per cent level of significance, while as negative coefficients for T_5, T_6 and T_{12} significant at 5 per cent level of significance. Seeds had negatively significant coefficient at 1 per cent level and at 5 per cent level of significance for T_1 and T_{12} and positive coefficients significant at 5 per cent level and 1 per cent level of significance for T_5 and T_6, respectively. In case of herbicide all treatments had negatively significant coefficient the results from the table further revealed that in case of urea, T_5, T_6 and T_{12} had positively significant coefficients wherein phosphorus had negatively significant coefficients for T_5 and T_{12} and positively significant coefficient for T_6. Potash was having negative coefficient for T_5 significant at 1 per cent level of significance and positive coefficient for T_6 significant at 5 per cent level of significance. The coefficient for FYM in T_6 was positively significant at 1 per cent level of significance. The coefficient for paddy straw in case of T_{12} was positively significant at 5 per cent level of significance. Likewise, coefficient for irrigation were positively significant for T_1 and T_5 significant at 1 per cent and 5 per cent level of significance, respectively and were negative for T_6 and T_{12} significant at 10 per cent and 1 per cent level of significance, respectively.

As far as machine labour was concerned, positive coefficients were observed for T_5, T_6 and T_{12} significant at 1 per cent, 5 per cent and 1 per cent level of significance respectively, while as negatively significant for T_1 at 5 per cent level of significance. Miscellaneous charges had positively significant coefficient 0.060 significant at 1 per cent level of significance and 0.014 significant at 1 per cent level of significance for T_1 and T_5, while as negatively significant coefficient at 5 per cent and 10 per cent level of significance for T_6, and T_{12}, respectively. The coefficient for σ^2 positively significant with the value of 0.007 significant at 1 per cent level of significance, 0.003 significant at 1 per cent level of significance, 0.002 significant at 1 per cent level of significance and 0.006 significant at 1 per cent level of significance for $T_{1,}T_5$, T_6 and T_{12}, respectively while as the coefficients of likelihood function were 52.065, 71.166, 74.623 and 54.954, respectively.

TFP index presented in Table 3 and revealed that for the overall period, it was found that all treatments exhibit decreased in productivity. During period II, and period III all treatments exhibits marginal decline. As far as period IV was concerned, there was also marginal decrease wherein during period V $T_1$and T_{12} observed marginal decline and T_6, T_{12} exhibits marginal increase in productivity. The overall period recorded marginal decline in all the treatments viz. T_1, T_5, T_6 and T_{12}.

The Table 4 revealed that treatments of rice and wheat observed efficiency change equal to one during entire period whereas during period I and period II, efficiency change was found to be greater than one for all four treatments where as during period III, period IV and period V efficiency changes were found to be less than one for all treatments of rice-wheat system.

The results from table further indicated that during period I and period II, rice-wheat system observed technical change less than one indicating technical regress during these periods. As far as period III and period IV were concerned, they also observed technical regress werein during period V $T_{1,}$ $T_{6,}$ and T_{12} observed technical progress andT_5 recorded technical regress during the same period. The overall period exhibits technical regress in all four treatments of rice-wheat system. The results from table revealed that most of the periods observed technical regress which is of prime concern as productivity gains are more closely associated with technological progress which in this case is very low, the reason might be that in research field same technologies had been used over the entire period indicating that if technologies are changed from time to time there is larger scope for productivity gains.

As observed from the table, during period I, period II, period III and period IV, efficiency change was greater than technical change. While as during period V, treatments of rice-wheat system observed technical change greater than efficiency change. The overall period observed that efficiency change was greater than technical change in all cases which means that technologies were dwelling.

The TFP index was regressed on indices of investment in crop research, agricultural extension, percentage share of nutrient supplied through FYM, area under high yielding varieties of rice and wheat and annual rainfall over the period of 1986-87 to 2010-11. A summary of variables used in the decomposition analysis given in Table 5 observed that the mean of dependent variable (TFP) 16.16, that of independent variables like research stock, extension stock, HYV of rice and wheat, Percentage share of FYM over total nutrient supply and rainfall were 62.60, 3.13, 62.61, 63.70, 0.34 and 140.99, respectively. Table 6 further provided the estimated coefficient of research which was 0.72, extension 4.26, HYV of rice had coefficient of 2.77, HYV of wheat had coefficient of -2.16, FYM recorded coefficient of -228.96 and rainfall was -0.12.

Table 1: indices of total factor productivity for rice-wheat cropping system

Periods	Treatments	Efficiency change	Technical change	TFP change
Period I	T_1	1.002	0.984	0.985
	T_5	1.002	0.987	0.989
	T_6	1.002	0.989	0.991
	T_{12}	1.002	0.981	0.982
Period II	T_1	1.001	0.979	0.980
	T_5	1.001	0.985	0.986
	T_6	1.001	0.988	0.989
	T_{12}	1.001	0.984	0.985
Period III	T_1	0.995	0.980	0.975
	T_5	0.995	0.988	0.983
	T_6	0.995	0.990	0.985
	T_{12}	0.995	0.981	0.976
Period IV	T_1	0.996	0.990	0.986
	T_5	0.996	0.993	0.989
	T_6	0.996	0.995	0.991
	T_{12}	0.996	0.986	0.982
Period V	T_1	0.997	0.986	0.983
	T_5	0.997	1.004	1.000
	T_6	0.997	1.006	1.002
	T_{12}	0.997	0.997	0.994
Overall period	T_1	0.999	0.983	0.982
	T_5	0.999	0.986	0.985
	T_6	0.999	0.989	0.988
	T_{12}	0.999	0.982	0.981

Table 2: Ordinary least square (OLS) and maximum likelihood estimates (MLE) for rice- wheat cropping system (Overall period)

Regression parameters	T_1		T_5		T_6		T_{12}	
	OLS	MLE	OLS	MLE	OLS	MLE	OLS	MLE
Constant (β_0)	1.215**	1.220*	3.738**	3.746**	1.209***	1.223**	0.796***	0.445***
Human labour (β_1)	0.591*	0.594*	-0.323**	-0.324**	-0.132*	-0.133**	-0.471***	-0.563**
Seeds (β_2)	-0.288*	-0.293*	0.069*	0.072**	0.116**	0.117*	-0.219*	-0.271**
Herbicide (β_3)	-0.208**	-0.213*	-0.1098**	-0.110**	-0.099**	-0.098***	-0.123**	-0.135**
Urea (β_4)	NA	NA	0.381***	0.383***	0.032*	0.034*	0.107*	0.103*
Phosphorous (β_5)	NA	NA	-0.087**	-0.088*	0.054*	0.046*	-0.106**	-0.052***
Potash (β_6)	NA	NA	-0.018***	-0.019*	0.101*	0.102**	NA	NA
FYM/ paddy straw(β_7)	NA	NA	NA	NA	0.030*	0.031*	0.035*	0.036**
Irrigation (β_8)	0.126*	0.129*	2.407**	2.406**	-0.034**	-0.033***	-0.054*	-0.057*
Machine labour (β_9)	-0.357***	-0.350**	0.010*	0.013*	0.249**	0.251**	1.081*	1.199*
Miscellaneous (β_{10})	0.063**	0.060*	0.015*	0.014*	-0.135***	-0.137**	-0.103*	-0.088**
σ^2	0.008*	0.007*	0.004**	0.003*	0.003**	0.002*	0.008*	0.006*
log likelihood function	51.810	52.065	71.175	71.166	74.621	74.623	54.662	54.954

Note: * significant at 1% los, ** significant at 5% los and *** significant at 10% los. NA indicates Not applied

Table 3: sequential Total Factor Productivity Index

Total Factor productivity	Declining (<1)			No Change =1	Increasing (>1)		
Time Period	Large (≤0.5)	Small (0.501-0.799)	Marginal (0.8-0.999)		Marginal (1- 1.399)	Small (1.4-1.999)	Large (≥2)
Period I							
		T_6	T_1, T_5, T_{12}				
Period II							
			T_1, T_5, T_6, T_{12}				
Period III							
			T_1, T_5, T_6, T_{12}				
Period IV							

			T_1,T_5, T_6, T_{12}				
Period V							
			T_1, T_{12}		T_5, T_6,		
Overall period							
			T_1,T_5, T_6, T_{12}				

Table 4: decomposition analysis of total factor productivity into efficiency change and technical change

Component	Direction of Change	Period I	Period II	Period III	Period IV	Period V	Overall Period
Efficiency Change	Increasing (EFFCH> 1)	T_1, T_5, T_6, T_{12}	R, T_1, T_5, T_6, T_{12}				
	No change (EFFCH =1)						
	Decreasing (EFFCH<1)			T_1, T_5, T_6, T_{12}	T_1,T_5, T_6,T_{12}	T_1, T_5,T_6, T_{12}	T_1, T_5, T_6, T_{12}
Technical Change	Technical progress (TECHCH>1)					, T_1, T_6, T_{12}	
	No change (TECHCH=1)						
	Technical Regress (TECHCH<1)	T_1,T_5, T_6,T_{12}	T_1, T_5, T_6,T_{12}	T_1, T_5, T_6, T_{12}	T_1,T_5, T_6,T_{12}		
Component whose contribution to TFP is greater	Efficiency change (EFFCH>TECHCH)	T_1, T_5,T_6,T_{12},	T_1, T_5, T_6,T_{12},	T_6, T_{12}	T_1, T_5,T_6, T_{12}		T_1, T_5,T_6, T_{12}
	Technical Change (TECHCH>EFFCH)					T_1, T_5,T_6, T_{12}	

Table 5: Summary of variables used in decomposition analysis of TFP

Variable	Description	Mean	Standard Deviation	CV	Compound Growth Rate
Dependent variable					
TFP	Total factor productivity Index	16.16	74.08	458.41	7.04*
Independent variables					
RCH	Research Stock in `/ha GCA	62.60	33.56	53.61	10.54*
EXT	Extension Stock in ` /ha GCA	3.13	1.42	220.42	7.87*
RHY	Percentage area of rice under HYVs	62.61	34.83	55.63	9.98*
WHY	Percentage area wheat under HYVs	63.70	35.49	55.71	11.09*
FYM	Percentage share of FYM over total Nutrient supply	0.34	0.09	26.47	3.32*
YRN	Rainfall (mm)	140.99	320.18	227.09	-0.48

Note: CV is the coefficient of variation * significant at 1% los,

Table 6: TFP decomposition analysis: Estimated parameters with lag structure

Variables	Coefficients	Standard Error
Intercept	176.34*	147.04
RCH	0.72*	0.88
EXT	4.26*	55.23
RHY	2.77*	4.48
WHY	-2.16	5.33
FYM	228.96*	347.54
YRN	-0.12	0.07
R^2	0.78*	
Adjusted R^2	0.76**	

Note: * significant at 1% los, ** significant at 5% los

Table 7: TFP decomposition analysis: Estimated parameters with lag structure

Variables	Coefficients	Standard Error
Intercept	176.34*	147.04
RCH	0.72*	0.88
EXT	4.26*	55.23
RHY	2.77*	4.48
WHY	-2.16	5.33
FYM	228.96*	347.54
YRN	-0.12	0.07
R^2	0.78*	
Adjusted R^2	0.76**	

Note: * significant at 1% los, ** significant at 5% los

S. No	Name	Designation/ Division
1	Dr. Huma Sehar*	Agri. Econ and Statistics, SKUAST-J
2	Dr. Jyoti Kachroo*	Prof. Agri. Econ and Statistics, SKUAST-J
3	Dr. Mudasir Iqbal*	Agri. Econ and Statistics, SKUAST-J
4	Dr. Dileep Kachroo**	Chief scientist & Head Agronomy, SKUAST-J

References

1. Anger DJ, Lovell CAK, Schmiidt P. Formulation of Stochastic Frontier Production Function Models. Journal of Econometrics. 1977; 6:21-37.
2. Anonymous. ICAR: Vision 2020, Indian Council of Agricultural Research, New Delhi, India, 1999.
3. Anonymous. Farmland Investment a Growing Phenomenon, Jagathi Agrowtechs Private Ltd, 2004.
4. Anonymous, Agricultural Statistics At a Glance 2010," Economics And Statistics, Ministry of Agriculture, Government of India, New Delhi, 2010.
5. Anonymous. Chapter 8: Agricultural Survey, Central Statistics Office Ministry of Statistics and Programming Government of India, New Delhi, 2011.
6. Barnett V, Johnston AE, Landau S, Payne RW, Welham SJ, Rayner AI. Sustainability: the Rothamsted experience. In: Barnett V, Payne R, Steiner R. (Eds.), Agricultural Sustainability: Economic, Environmental and Statistical Considerations. Wiley, Chichester, UK, 1995, 171-206.
7. Bauer PW. Recent Development in the Econometric Estimation of Frontiers. Journal of Econometrics. 1990; 46:39-56.
8. Battese GE, Coelli TJ. Frontier Production Function, Technical Efficiency and Panel Data: with application to paddy farmers in India. Journal of Productivity Analysis, 1992; 3:387-399.
9. Battese GE, Coelli TJ. A Model for Technical Inefficiency Effects in Stochastic Frontier Production Function for Panel Data. Empirical Economics. 1995; 20:325-332.
10. Caves Douglas W, Larutis RC, Diewart WE. The Economic Theory of Index Numbers and the of Measurement Input, Output Productivity. Econometrica. 1982; 50:1393-1414.
11. Chavan KR. Sustainability of Agriculture: Issues & Challenges. The International online journal. 2011; 4(1):53-56.
12. Coelli TJ, DSP Rao. Total Factor Productivity Growth in Agriculture: A Malmquist Index Analysis of 93 Countries, 1980-2000. Agricultural Economics. 2005 32(1):115-134.
13. Fare R, Grosskopf S, Norris M, Zhang Z. Productivity Growth, Technical Progress and Efficiency Changes in Industrial Countries. American Economics Review. 1994, 66-89.
14. Farrell M. The Measurement of Productivity Efficiency. Journal of Royal Statistical Society. Series A. 120(3):253-290.
15. Kumbhakar S, Gosh SC, McGuckin JT. A Generalised Production Frontier Approach for Estimating Determinants of Inefficiency in US dairy farm. Journal of Business and Economic Statistics. 1991; 9:276-286.
16. Meeusen W, Van den Broeck J. Effeciency Estimation from Cobb-Doughlas Production Function with Composed Error. International Economic Review. 1977; 18:435-444.
17. Pitt MM, Lee LF. Measurement and Source of Technical Inefficiency in the Indonesian Weaving Industry. Journal of Development Economic. 1981; 9:43-64.
18. Schmidt C, Sickles RC. Production Frontiers and Panel Data. Journal of Business & Economic Statistic, 1984, 2(4).