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Total factor productivity and returns to investment in onion research in Maharashtra

Nirpal RS, VG Pokharkar, CM Gulve and RA Shelke

Abstract
The proportion of total output to the whole number of resources/factors is used to measure total-factor productivity (TFP), also known as multi-factor productivity. Growth in TFP explained the contribution of yield growth not explained by growth in normally measured employed manpower and investment in inputs in the production when specific assumptions about production technology are made. Total factor productivity is a count of economic efficiency that explains some of the discrepancies in per-capita income among countries. TFP measures the net growth of output per unit of total inputs. In this study, estimation of total factor productivity in onion crop and returns to investment in onion research in Maharashtra is attempted. For the study, the time series data on cost of cultivation of onion was collected (1990-91 to 2018-19) from official records of state cost of cultivation scheme to fulfil the objectives. The onion output index grew from 1.12 in 1992-93 to 1.85 in 2018-19. In 2011-12, output growth fell to 0.99 per cent, the lowest since 2002-03. (0.83). In 2007-08, the largest /highest output index was recorded. For the past twenty-nine years, the average output index has been 1.35. The average onion input index was 1.05 for twenty- nine years. The year with the highest TFP index was 2016-12. (2.29). The result indicates that total factor productivity index of paddy grew at 0.53 per cent per annum. Public research investment significantly contributed (0.14***) to TFP growth in onion. The additional investment of one rupee in paddy research generated additional income of 29.87 RS, indicating substantial rate of returns to investment with internal rate of return of 31.75 on research in paddy in Maharashtra. The total factor productivity in paddy crop registered a substantial growth with profitable returns in Maharashtra. Hence the Government should allocate substantial funds to public research in paddy for productivity improvement of paddy crop providing food security to masses.

Keywords: Total factor productivity, onion, estimated value of marginal product, internal rate of return

Introduction
Onion (*Allium cepa* L.) is one of the most popular vegetable that form of the daily diet. Allium cepa is a major commercial vegetable crop g in India. The yield of onions is predicted to be 26.74 million tonnes. For the year 2019, the world's onion area, production, and productivity were 5.1 Mha, 99.94 MT, and 19.4 t/ha, respectively (FAO Website). In the World's India is the second largest onion grower, trailing only China, however India's onion productivity is poor, at 17.01 tonne/ha, when draw an analogy among China and other countries by its nature Egypt, the Netherlands, and Iran, among others. India ranked seventh in onion productivity, despite being a poor performer in comparison to different countries. Onion is an indispensable item in every kitchen as condiment and vegetable. It is used either in raw form and dehydrated form to add favour and taste to Indian cousins. Since onion has medicinal value, it is used in some pharmaceutical preparation also. It has many uses as, folk remedies and recent report suggests that onion play a part in preventing heart diseases and other ailments. Onion bulb is rich in minerals like phosphorous, calcium and carbohydrate. Indian agriculture has undergone technological change at different rates across regions and among different crops. Rapid growth in rice production has resulted in substantial increases in the marketable surplus of onion. Many of the benefits of higher efficiency in the use of inputs and lower unit costs of production that technological change has generated have been passed on from farmers to consumers in the form of lower prices. Rice is a principal vegetable crop, which nearly one-fourth of the gross irrigated area in India occupies. Majority of agricultural and food policy initiatives over the period were largely cantered on rice and also wheat. However, the public sector Research and Development (R&D) wing has given a top priority to the rice improvement in terms of resource allocation of both capital and human resources.

Material and Methods

1. Total factor productivity

Total factor productivity has a considerable impact on economic instability, economic growth and cross-national per capita income differences. Factor in total Productivity is a phrase that refers to the amount of change in output that is not taken into consideration account by changes in traditional inputs like land, labour, and capital. TFP is strongly correlated with output and hours worked at business cycle frequencies. TFP refers to the unexplained variation in output after accounting for changes in output due to conventional factors in the production function estimation. As a result, the efficiency and intensity with which inputs are used in production determines its level. The approach to estimation of TFP can be classified into three types: index-number method (Tornqvist Index), growth accounting method, and econometric methods.

Solow (1957) was the first to propose a framework for growth accounting. TFP is measured as a leftover factor in this approach, which refers to the segment of output growth that is not considered by growth in the rudimentary inputs. This method calculates factor productivity indices, primarily the rate of change of total factor productivity indices, to approximate technological change (Christensen, 1975). The ratio of the index of net output to the index of total factor inputs is used to compute the TFP index. The total factor inputs index is calculated as a weighted average of the indices of labour, capital, and land inputs, with the respective income proportions of three variables as weights. The separation of change in yield due to the quantities of factors of production from residual influences, such as technological progress, learning by doing, etc., is a key feature of the GAA. The GAA uses three main indices: I the Kendrick Index (KI), (ii) the Solow Index (SI), and (iii) the Translog Index (TI) (TLI).

The Divisia-Tornqvist Theil index of TFP is widely utilized.for estimation of total output, input, and TFP indices can be specified as:-

Total Output index: TOIt/ TOIt_1= U j(Qjt / Qjt-1)R+R1)1/2 (1)

Total Input index: TIIt/ TIIt_1= Ui(Xu/ Xit-1)(S+S*1)1/2 (2)

Where,
Rjt = Share of jthoutput in total output,
Qjt = Output of the jthcommodity,
Sjt = Share of the ithinput in total input cost, and
Xu = Quantity of the ithinput

For the multi-factor productivity measurement over a long period of time, chaining indexes for successive time periods is preferable. With chain linking, an index is calculated for two successive periods, t and t-1, over the whole period 0 to T (sample from time t=0 to t=T) and the separate indexes are then multiplied together:

TOI(t) = TOT(1).TOI(2)…….TOI (t-1) (3)

TII(t) =TII(1).TII(2)……….TII (t-1) (4)

Finally, the TFP index is expressed as

TFPt = TO/TH, …………… (5)

For the onion crop, the output index, input index, and TFP index are created. To create the output index, time series data from 1990 to 2018 were used the main product, by product, and prices, whereas to create the input index, time series data from human labour, bullock labour, machine labour, seeds, manure, fertilizer (NPK), irrigation, and input prices were used. Finally, by dividing the output index to the input index, the TFP index is calculated. We specified that the index is equal to 1.00 in a specific year, i.e., we used 1990-91 as the base year and constructed the TFP chain index because it gives annual changes in the productivity of onion over time.

Throughout the study period, the Chain-linking index consider the changes in relative values/costs. This technique has the advantage of reducing biases by ensuring that there is no single year has a prominent role in deciding the share weights. For the years 1990-91 to 2018-19, time series data on onion costs and returns were amassed and assembled from the cost of cultivation scheme, Department of Agricultural Economics, MPKV, Rahuri.

The following are the TFP indices

Total output index

(TOI) = TOIt/TOIt-1=∏j(Qjt/Q jt-1)(Rjt+Rjt-1)1/2

Total input index

(TII) = TIIt/TIIt-1=∏j(Xjt/Xjt-1)(Sjt+Sjt-1)1/2

Total factor productivity index (TFPI) of tth year is 100 times the ratio of TOI, to the TII and is given by,

TFPIt= (TOIt/TIIt) x 100

Input price index is given by,
Where,
Rjt = Share of jth output in total revenue
Qjt = Output ‘j’
Sjt = Share of ith input in total input cost
Xit = input ‘i’
Pit = Price of ith in period ‘t’

The preceding equation yields the total output, total input, total factor productivity, and input price indices for the specified period ‘t' by setting TOI t-1, TIIt-1, and IPIt-1 equal to 100 in the first year.

The chain-linking index accounts for changes in relative values/costs over the study period. This method has the advantage of reducing biases by ensuring that no single period has a dominant role in determining share weights.

2. Sources of TFP growth

To quantify the contribution of different factors in TFP growth and examine the determinants of TFP, the Cobb-Douglas type of production function was carried out. The TFP index was regressed against the following variables as a means to access the determinants of TFP:

$$Y = ax_1^{b1}X_2^{b2}x_3^{b3}x_4^{b4}x_5^{b5}x_6^{b6}\ x_7^{b7}\ x_8^{b8}x_9^{b9}\ x_{10}^{b10}e^u$$

Where,
Y=Total factor productivity index (TFP)
A=Constant term
X1=Research investment (Rs. /ha)
X2=Rural Literacy (%)
X3=Rainfall (mm)
X4=Road Density (km.)
X5=N to P ratio
X6=GIA (%)
X7=Cropping intensity (%)
X8=Electricity (Agril. Consumption GWh)
X9=Max. Humidity
X10=Min. Humidity

T = Time variable (years 1, 2, 3…. n)
U = Error term
(b1 to b10) are regression coefficients of respective variables)

3. Impact of research and extension on income generation.

A) Estimated value of marginal return

The data was compiled from time series data from various years. The value of the marginal product of research was estimated utilising the flexibility of TFP in researchas shown below.

EVMP(R) = b*(V*TFP share/R)

Where,
R: Research investment (Per ha)
B: TFP Elasticity of research investment
V: TFP is associated with a high value of production.
EVMP: Estimated Value of Marginal Product

4. Internal rate of return

Internal rate of return, also designated as Marginal efficiency of capital or Yield on Investment, is a measure of how profitable an investment is. IRR is the interest rate which was earned on the unrecovered balance over the life of an investment in this manner irrecoverable balance is zero at the end of that time. The discount rate at which an investment's NPV (Net present value) becomes zero is known as the "IRR." Alternatively stated, a discount rate is a figure that compares the present value of an investment's future cash flows to the primary outlay.

IRR = (Lower Discount Rate) + (Difference between the Two Discount Rates)*(Present Worth of Cash Flow at the Lower Discount Rate/Absolute Difference between the Present Worth of the Cash Flow at the Two Discount Rates)

Result and discussions

1. Total factor productivity

Table 1 displays the onion output, input, and TFP indices. For the study period 1990-91 to 2018-19, these indices were computed with the help of Tornqvist index method. Because current prices are considered construct the weights, the Tornqvist-Theil index has the benefit of accounting for changes in input quality. The TFP index is determined by taking the ratio of output index by the input index. The output per unit of non-input is referred to as TFP. Table 4.11 proves that the TFP for onion has increased since 1991-92, when it was 1.78. The TFP index was less than one in 1993-94, 2001-02, 2006-07, 2009-10, 2010-11, 2013-14, and 2015-16, which could be because of the drought conditions at the time. The year with the highest TFP index was 2016-12. (2.29). For the past 29 years, the average TFP index has been 1.31. TFP was greater than one for the majority of the years, indicating that as TFP raises, the cost of production falls, helping to keep prices stable. The onion output index grew from 1.12 in 1992-93 to 1.85 in 2018-19. In 2011-12, output growth fell to 0.99 per cent, the lowest since 2002-03. (0.83). In 2007-08, the largest /highest output index was recorded. For the past twenty-nine years, the average output index has been 1.35. There were significant fluctuations in the input index, which fell from 1.30 in 1990-91 to 0.90 in 2018-19. For twenty-nine years, the average onion input index was 1.05.

Table 1: Input, Output, TFP index and share of input and TFP of onion.

Sr. No.	Year	Input Index	Output Index	TFP Index	Input Share	TFP Share
1	1990-91	1.00	1.00	1.00	100.00	0.00
2	1991-92	1.30	2.30	1.78	56.33	43.67
3	1992-93	1.08	1.12	1.04	96.01	3.99
4	1993-94	1.01	0.78	0.78	128.59	-28.59
5	1994-95	0.97	1.79	1.84	54.32	45.68
6	1995-96	1.39	2.10	1.51	66.08	33.92
7	1996-97	0.90	1.19	1.33	75.34	24.66
8	1997-98	1.04	1.20	1.15	86.90	13.10
9	1998-99	1.01	1.07	1.06	94.28	5.72
10	1999-2000	1.03	1.08	1.05	95.69	4.31
11	2000-01	0.91	1.21	1.34	74.72	25.28
12	2001-02	1.25	1.11	0.89	112.63	-12.63
13	2002-03	0.77	0.81	1.06	94.70	5.30
14	2003-04	1.78	2.17	1.22	81.93	18.07
15	2004-05	0.64	1.05	1.63	61.45	38.55
16	2005-06	0.97	1.98	2.04	48.91	51.09
17	2006-07	1.09	0.88	0.80	124.84	-24.84
18	2007-08	1.16	2.32	2.00	49.89	50.11
19	2008-09	0.94	1.55	1.65	60.75	39.25
20	2009-10	1.10	0.63	0.57	175.63	-75.63
21	2010-11	1.53	1.27	0.83	120.06	-20.06
22	2011-12	0.81	0.99	1.22	81.73	18.27
23	2012-13	0.99	1.18	1.19	83.89	16.11
24	2013-14	1.01	0.80	0.79	126.27	-26.27
25	2014-15	0.98	1.18	1.20	83.06	16.94
26	2015-16	1.01	0.99	0.98	101.70	-1.70
27	2016-17	0.85	1.95	2.29	43.73	56.27
28	2017-18	0.97	1.75	1.81	55.25	44.75
29	2018-19	0.90	1.85	2.06	48.45	51.55
	Total	30.35	39.28	38.12	2483.14	416.86
	Average	1.05	1.35	1.31	85.63	14.37

2. The compound growth rates of input, output and TFP index

Table 2. Shows the annual average growth rates in the total output index (TOI), total input index (TII), and total factor productivity index (TFPI) over time using an exponential function. The accessibility of data on inputs and outputs from the cost of cultivation study guides the period of analysis for onion. The compound growth rate of input, output, and TFP indices were estimated for 29 years from 1990-91 to 2018-19 and for three periods in order to evaluate growth performance

of TFP of onion in Maharashtra. Period I (1990-91 to 1999-2000), Period II (2000-01 to 2009-10) and Period III (2010-11 to 2018-19), as well as the entire period (1990-91 to 2018-19).

Input growth

In Maharashtra, annual growth in input use increased (0.44%) during Period II (2000-01 to 2009-10), but output growth decreased (0.28%), indicating that more input is being used. Input use decreased by 3.09 per cent for Period III (2010-11 to 2018-19) and 0.45 per cent for the overall Period (1990-91 to 2018-19), respectively, while output increased. Due to inward movement in the production function, such changes result in positive TFP growth.

Output growth

For Period III (2010-11 to 2018-19) and the Overall Period (1990-91 to 2018-19), output growth occurred 3.68 per cent and 0.07 per cent, respectively, due to technological changes. The output growth of onion has been decreasing throughout the sub-periods, i.e., Period I and Period II.

TFP growth

The growth in TFP, which is a measure of productivity, has shown significant variation over time. For the third Period (6.77 per cent) and overall period, onion has reaped the greatest benefit from technological innovations (0.53 per cent). The study of TFP growth in Maharashtra onion resulted in a strong belief that onion has experienced technological advancement.

Table 2: CGR of Input, Output and TFP Index

Sr. No.	Period	Input Index	Output Index	TFP Index
1	Period I (1990-91 to 1999-2000)	-0.97	-1.75	-0.79
2	Period II (2000-01 to 2009-10)	0.44	-0.28	-0.72
3	Period III (2010-11 to 2018-19)	-3.09	3.68*	6.77 **
4	Overall (1990-91 to 2018-19)	-0.45	0.07	0.53

*, ** and *** indicate significance at 10, 5 and 1 % level

The improvement in total factor productivity especially in recent years is due to non-input factors such as rainfall, road length, markets, better management practices, investment in research and extension etc. The contribution/involvement of technological change to onion output growth was positive and respectable across sub-periods. This suggests that the productivity growth rather than the input growth is the main driver of onion production in Maharashtra. The MPKV, Rahuri has released new and improved varieties *viz*; Baswant -780, N-2-4-1, Phule Samarth etc. to increase the productivity which have qualities like less duration and good for storage. Agricultural universities thus take part of onion total factor productivity.

3. Determinants of Total Factor Productivity (TFP) growth in onion

Variation in efficiency as well as changes in best practise are all part of productivity growth. When it comes to the sources of productivity changes, the technical change component is more important. Changes in the variables that cause TFP to grow are critical for estimating how much each of these sources contributes to TFP growth. An effort was made in this section to analyse the determinants of onion total factor productivity in Maharashtra.

The TFP index was regressed against the variables of research investment, maximum humidity, minimum humidity, rural literacy, rainfall, cropping intensity, electricity consumption, road density, N/P ratio, and gross irrigated area to investigate the determinants of TFP. The contribution of various factors to TFP growth, such as research investment, rural literacy, rainfall, road density, N/P ratio, gross irrigated area, humidity (maximum and minimum), and so on, was quantified using the TFP index (Table No.4.14).

Table 3: The table showing in a variables coefficients and standard error

Sr. No	Variables	Coefficients	Standard error
1	Intercept (a)	11.27	29.58
2	Research Investment (`/ha) (X_1)	0.14**	0.05
3	Rural Literacy (%) (X_2)	-5.78	13.76
4	Rainfall (mm) (X_3)	-0.56	0.93
5	Road Density (km.) (X_4)	1.12**	0.53
6	N to P ratio (X_5)	0.66	1.74
7	GIA (%) (X_6)	0.15**	0.07
8	Cropping intensity (%) (X_7)	5.28	6.65
9	Electricity (Agril. Consumption GWh) (X_8)	-0.31	1.73
10	Max. Humidity (X_9)	3.98	6.87
11	Min. Humidity (X_{10})	0.85**	0.44
12	R^2	0.76	
13	N (No. of observations)	18	

****, ** and * indicate significance at 1,5 and 10 % level of significance

The research investment has been a significant variable of TFP growth in onion, according to Table No.4.14. TFP enhancement in onions has benefited from investments in research and technology transfer (extension). Assured irrigation water and low humidity have played an important role in TFP levels among natural resources. When it comes to infrastructure, road density has been found to be the most important determinant of TFP. The density of the roads was used as a proxy for infrastructure. Road density would create an input-output market interface and a favourable environment for technology adoption and investment induction in agriculture.

To compute the elasticity of TFP with respect to research investment and to assess the impact of research, regression coefficient estimates were used to assess the effect of various sources of TFP. TFP elasticities were 0.14, 1.12, 0.15, and 0.85, respectively, for research work, road density, gross irrigated area, and minimum humidity. They aided onion TFP growth in a positive way. It shows that a 1% increase in research investment will result in a 0.14 per cent increase in TFP. It implies that government spending on agricultural research and extension plays a bigger role in increasing agricultural productivity. The ratio of nitrogen to phosphorus nutrients was used as a proxy for fertilizer balance. The impact of rural literacy, on the other hand, was found to be negative and non-significant. The migration of rural literates to urban areas due to increased non-farm employment opportunities and distress-like situations in farming sector could explain such a result. As a result, they possibly not directly contribute to increased agricultural productivity.

The estimated R2 value of 0.76 indicates that ten independent variables that were included in the model jointly explain 76 per cent of the variation in TFP. The rainfall was negative (-0.56) and unimportant. It was discovered that the total factor productivity of onion was inversely affected by uneven, low, and dry rainfall spells. In addition, the analysis of TFP determinants shows that government expenditure on research, education, and extension, gross irrigated area, road density, and minimum humidity are the key drivers of onion productivity in Maharashtra.

4. Returns to investment in onion Research

1. Estimated Value of marginal product

The marginal product is the amount of money that is added to total income resulting from a one-rupee extra investment. The EVMP was calculated to calculate monetary returns. The first way is to decompose the growth of TFP to various factors, including research, and the second step is to estimate the marginal/additional product for research investment using the product of research stock elasticity and average product value of research. The regression results were used to calculate the relative contribution of onion TFP growth to research investment. The estimated value of marginal product was calculated and presented below using TFP's elasticity with respect to the research investment variable. The research investment regression coefficient should be positive and statistically significant when estimating the EVMP. The per hectare value of output associated with TFP and research cost is required for estimating EVMP, and it can be found in Table 4.

Table 4: Research cost and output associated with TFP (per ha.)

Sr. No.	Year	Output Associated with TFP (Rs./ha)	Research Cost per ha (Rs./ha)
1	2002-2003	4892.63	131.99
2	2003-2004	8847.48	152.73
3	2004-2005	6675.98	116.96
4	2005-2006	8465.88	131.45
5	2006-2007	15075.63	98.50
6	2007-2008	10072.69	132.20
7	2008-2009	21771.72	107.02
8	2009-2010	14790.57	75.60
9	2010-2011	23971.73	51.65
10	2011-2012	10464.17	63.85
11	2012-2013	30652.43	60.13
12	2013-2014	25305.78	48.55
13	2014-2015	30799.86	48.27
14	2015-2016	24053.47	110.42
15	2016-2017	15486.65	74.64
16	2017-2018	36103.45	62.95
17	2018-2019	19976.79	46.08
18	2019-2020	28040.12	59.21
	Total Cost	335447.11	1572.27
	Average	18635.95	87.34

When the value of the percentage proportion of research in TFP growth is multiplied by the average value of production, the research-induced value of production (V) can be calculated (product of production and price). The ‘V' is used to compute the research's estimated value of marginal product (EVMP), which is calculated as EVMPr = br (V/R). R is the average value of research stock/cost, and br is the elasticity of research stock.

EVMP(R) = b*(V*TFP share/R)

Where, R: Research Investment
b: TFP Elasticity of Research Investment
V: Value of production associated with TFP
EVMP(R) = b*(V*TFP share/R)
= 0.14*(18635.95/87.35)
= 29.87
EVMP = Rs.29.87

When the EVMP is 29.87, it means that a one-rupee investment in onion research yielded Rs. 29.87 in additional income. When a marginal product has a value greater than one, it means that research in that commodity has produced sufficient output to justify investment.

Onion Research expenditure flexibility

With respect to research, the inverse of TFP elasticity provides flexibility in research spending.
Research expenditure flexibility =1/0.14 (Research elasticity)
= 1/ 0.14

Research expenditure flexibility =7.14

The estimated value was 7.14, implying that in order to accomplish a 1% increase in TFP, investments in onion research must be increased by 7.14 percent.

The hypothesis *i.e.*, onion research project has positive impact on output has been proved.

2. Internal rate of return

The internal rate of return (IRR) or economic rate of return (ERR) is a rate of return used in capital budgeting to measure and compare the profitability of investments. It is also called the “discounted cash flow rate of return” (DCFROR) or the rate of return (ROR). The internal rate of return is a metric used in financial analysis to estimate the profitability of potential investments. The internal rate of return is a discount rate that makes the Net Present Value (NPV) of all cash flows equal to zero in a discounted cash flow analysis. IRR is the annual rate of growth an investment is expected to generate. IRR is calculated using the same concept as NPV, except it sets the NPV equal to zero. IRR is ideal for analysing capital budgeting projects to understand and compare potential rates of annual return over time.

The marginal internal rates of returns to agricultural research were found to be between 30 and 35 per cent, indicating that agricultural research has provided attractive returns over the last 18 years. The IRR was calculated as follows:

IRR = (Lower Discount Rate) + (difference between the two discount rates) *(present worth of cash flow at the lower discount rate/absolute difference between the present worth of the cash flow at the two discount rates).

IRR = 30+ (5) *(1128.11/3258.42)
= 30+5*(0.35)
= 30+1.75
=31.75

IRR = Internal Rate of Return (IRR) to investment in onion research estimated to be 31.75 %. It means that one rupee invested in onion research generates additional income by 31.75 per cent annually.

It implies that every rupee invested in onion research yielded a return of 31.75 per cent per year, indicating that onion research is a highly profitable investment. The return on investment in onion research has been found to be very high.

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