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REMARKABLE ACHIEVEMENT IN ARHAR PRODUCTIVITY IN GUJARAT: THE CONTRIBUTION OF RESEARCH INVESTMENT AS REFLECTED BY TFP AND RRI

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ABSTRACT

The present study has analyzed the growth in TFP of arhar crop and its sources in Gujarat state from 1990-91 to 2011-12. The Tornqvist Theil Index has been used to calculate the total output index, total input index and TFP index. Two outputs and ten inputs have been used to construct output and input indices. The analysis shows that the arhar crop which registered negative TFP growth in 1990s, vitally revived during 2000s with significantly positive growth of total input, total output and TFP indices at the rate of 2.16, 5.06 and 2.84 per cent per annum, respectively, with a contribution of 67 per cent to output growth. During 2001-02 to 2011-12 though, the acreage has declined by 2.43 per cent, the production and productivity increased significantly at remarkable rate of 2.19 and 4.73 per cent per annum, respectively. This was contributed by the release of arhar varieties *viz.,* BDN-2 in 1984, GT-100 in 1992, GT-101 in 2003 and GT-Hy-1 in 2004, in the state and farmers preferred it, due to its superiority in yield, earliness and require less number of irrigations. Further, the analysis of sources of growth in TFP indicates that the government expenditure on research, extension education, development of canal irrigation, rural infrastructure in the state and *kharif* rainfall is the important drivers of arhar crop productivity in Gujarat. Returns to investment on arhar crop research have been found to be a highly paying proposition generating 55.50 per cent Internal Rate of Return. The arhar productivity in state increased from 851 kg/ha in 1990-91 to about 1185 kg/ha in 2012-13, though it is frequently constrained by moisture stress due to poor and uneven monsoon. To sustain the productivity of agricultural sector and to achieve projected rise in total production, policy attention will have to be paid to strengthen the sources which have positive impact on TFP growth by more public and private investments in under developed regions of the state to strengthen agricultural research, irrigation potential and rural infrastructure.

INTRODUCTION

The pigeon pea *Cajanus cajan* (L.) is the preferred pulse crop in dry land areas. It is also known as Arhar, Red gram and Tur, is an important multi-use shrub legume cultivated over 25 tropical and subtropical countries, either as a sole crop or intermixed with other crops. Being a legume, the pigeon pea enriches soil through symbiotic nitrogen fixation. India being the largest producer of tur in the world contributing to around 75 per cent of the world's total production that sums up to 31 lakh tones, but it is not into the exporter lists of at all, as the domestic consumption demand in the country is quite high.

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Gujarat is one of the leading states in agricultural production in the country. The Government has allocated a significant proportion of its resources to agricultural research in the state. Gujarat agricultural has recorded the fastest growth (above 9.6%) among all Indian states, since 2000. This is more than three times agricultural growth (2.9% per annum during 2000-01 to 2007-08) at all India level (Gulati, *et al.*, 2009). Therefore, it is imperative to look at current research efforts and their accuracy in order to address emerging regional research needs. This rate of growth in agriculture has been sustained by the technological progress embodied in the high yielding varieties with supporting public investment in irrigation, agricultural research and extension (R & E), and physical infrastructure. The most comprehensive measure of aggregate or sectoral productivity is Total Factor Productivity

(TFP). In view of the above, the present study was undertaken with the following specific objectives *viz.,* to measure the temporal changes in area, production and productivity of arhar crop in Gujarat; to estimate the growth of input and output indices of arhar crop, and to estimate the growth of Total Factor Productivity and its determinants, and returns to investment for arhar crop research in Gujarat.

MATERIALS AND METHODS

In the present study, TFP is estimated taking into account two outputs and ten inputs. Output index includes main product and by-product. The ten index comprises, seed (kg/ha), manure (tone/ha), fertilizers (kg/ha), human labour (man days/ha), bullock labour (pair days/ha), Irrigation (Rs/ha), insecticide/ pesticide (Rs/ha), miscellaneous cost (Rs/ha), depreciation (Rs/ha) and rental value of owned land (Rs/ha). The data on input, output and prices has been compiled from the Department of Agricultural Economics, Junagadh Agricultural University, Junagadh Campus, Junagadh collected under cost of cultivation scheme. The other required data were obtained from various publication sources.

Analytical framework

Index of total factor productivity (TFP) refers to that part of growth in output, which cannot be explained by growth in factor inputs like land, labour and capital. Index of Total factor productivity (TFPI) measured the growth of net output per unit of total factor input. The TFP is defined as the ratio of an index of aggregate output to an index of aggregate input. Theil Tornqvist discrete approximation to the Divisia index is a most useful method for TFPI computation. The use of TFP indices gained prominence since Diewert (1976, 1978) proved that Theil Tornqvist discrete approximation to the Divisia index was consistent in aggregation and superlative to linear homogeneous translogarithmic production function. The Tornqvist index is exact for the homogenous translog production function. The Divisia indices have two important attractive properties: (i) they satisfy the time reversal and factor reversal test for index numbers, and (ii) it is a discrete of the components, so that aggregate could be obtained by the aggregation of sub-aggregates (Kumar et al, 2008). An index of total factor productivity (TFP) compares changes in output with changes in aggregate inputs. In the present study also, the Tornqvist Theil index was used for computing the total output index, total input index and total factor productivity index. These indices were calculated as follows:

Total output index (TOI)

Total output indices were constructed using the Tornqvist Theil index approach as follows:

$$TOI_t / TOI_{t-1} = \prod_j (Q_{jt} / Q_{jt-1})^{(R_{jt} + R_{jt-1})^{1/2}}$$

Total input index (TOI)

$$TII_t / TII_{t-1} = \prod_j (X_{it} / X_{it-1})^{(S_{jt} + S_{it-1})^{1/2}}$$

Where, Q_{jt} = Output of j^{th} crop in t^{th} year.
Q_{jt-1} = Output of j^{th} crop in $(t-1)^{th}$ year.
R_{jt} = Output share of j^{th} crop in total revenue in t^{th} year.
R_{jt-1} = Output share of j^{th} crop in total revenue in $(t-1)^{th}$ year.
X_{it} = Quantity of i^{th} input used in j^{th} crop in t^{th} year.
X_{it-1} = Quantity of i^{th} input used in j^{th} crop in $(t-1)^{th}$ year.
S_{it} = Share of input 'i' in total input cost in t^{th} year.
S_{it-1} = Share of input 'i' in total input cost in $(t-l)^{th}$ year.

In the case of TFP for a single crop, revenue share refers to the share of main product and by-product in total revenue from the crop, while output includes main product and by-product. Thus, total output and input indices for arhar crop were prepared taking 1990- 91 as the base year.

Total factor productivity index (TFPI)

Total factor productivity indices was computed as the ratio of total output index (TOI) to total input index (TII).

$$TFPI_t = (TOI_t / TII_t) \times 100$$

The estimation of input, output and TFP growth rates for any specified was done by fitting an exponential (or semi-log) trend equation to the three-yearly moving averages of input, output and TFP indices, respectively.

Sources of TFP growth

The changes in the variables, that produce growth in TFP, have vital importance to estimate how much each of these sources contributes to the growth of TFP. As an input to public investment decisions, it is useful to understand the relative importance of these productivity-enhancing factors in determining productivity growth. To examine the determinants of TFP, a multiple regression technique in double log functional form was carried out. In order to assess the determinants of TFP, the TFP index was regressed against the following variables:

RES_STOK (research stock per ha of crop area);
EXT_STOK (extension stok per ha);
LIT_R (the proportion of rural population which is literate);
NPRATIO (ratio of N to P_2O_5 nutrients used);
CI (cropping intensity, %);
IRR_GW (groundwater irrigated area to total irrigated area, *i.e.* GWIA/GIA);
RAIL (rail density, km per 100 sq km);
IRR_INTEN (gross irrigated area to net irrigated area *i.e.* GIA/NIA);
IRR_POTEN (is the ration of irrigation potential to utilization in state;
IRR_CANAL is per cent canal irrigated area in state; and
RAINFALL is average total rainfall per year in state.

Regression analysis was attempted using the above variables and by clubbing together variables related to natural resources (NARI) and infrastructure (INF). Three variables representing natural agricultural resources were clubbed together by taking their average as:

1/3 CI + 1/3 NPRATIO + 1/3 IRR_GW.

Similarly, infrastructural index (INF) was computed from infrastructural variables as:

0.6 RAIL + 0.1 ELECT_AG + 0.3 IRR_INTEN)

[the weights 0.6, 0.3 and 0.1 were based on the experts judgement]. Model 1 below uses NARI and INF indices to estimate the effect of various factors on TFP. All major individual variables representing natural resources and infrastructure were incorporated in model 2. Accordingly, the specification of regression equations was stated as:

Model 1: TFP = f (RES_STOK, EXT_STOK, LIT_R, NARI, INF,)

Model 2: TFP = g (RES_STOK, EXT_STOK, LIT_R, CI, NPRATIO, IRR_GW, RAIL, IRR_INTEN, IRR_POTEN, IRR_CANAL, RAIN)

Estimation was undertaken using a fixed effect approach for the pooled cross-section time seris state-level dataset, with corrections for serial correlation and heteroskedasticity (kmenta, 1981). Following Evenson et al. (1999), the research stock variable was constructed by summing up research investment of five years by assigning weights as 0.2 in the year t-2, 0.4 in the year t-3, 0.6 in the year t-4, 0.8 in the year t-5 and 1.0 in the year t-6. The extension stock variable was constructed by summing up three years' extension investment by assigning weights as 0.2 in the year t-1, 0.4 in the year t-2, and 1.0 in the year t-3.

Returns to research investments

The value of marginal product for research is estimated as per below Equation:

EVMP (RES_STOK) = b_i (V/ RES_STOK)

Where, V is the value of crop production associated with TFP (value of output for crop multiplied by the same share of TFP in total output), RES_STOK is the research stock and b_i is the TFP elasticity of research stock estimated from TFP models 1 and 2. The benefit stream was generated under the assumption that the investment made in research in the year t-i will start generating a benefit after a lag of five years, at an increasing rate during the next six years, will remain constant for the next six years and thereafter, it will start declining (one can also take the lag structure of 6,6,6 or 9,9,9). Following Evenson and Pray (1991), an investment of one rupee in the year t-i will generate a benefit eqal to 0.1 EVMP in the year t-i+6, 0.2 EVMP in the year t-i+7,....... so on till t-i+11, and it will 0.9 EVMP in the year t-i+12. After this, the benefit will be equal to EVMP up to the year t-i+18. Then, the benefit from the year t-i+19 onwards will again star declining and will be equal to 0.9 EVMP in the year t-i+19, and 0.8 EVMP in the year t-i+20, and so on. This benefit stream can be discounted at the rate, say 'r', at which the present value of benefit is equal to one. Thus, 'r' was considered as the marginal internal rate of return to public research investment.

Table 1. Major state wise production of arhar in India (lakh tonnes)

States	1990-91	1995-96	2000-01	2005-06	2010-11	2011-12	2012-13	2013-14	2014-15(p)
Gujarat	3.65	2.78	1.24	2.76	2.73	2.58	2.70	2.09	2.35
Andhra Pradesh	0.74	1.01	2.19	3.01	2.65	1.46	2.51	2.43	1.65
Karnataka	1.75	2.02	2.64	4.37	5.29	3.54	3.66	5.88	5.07
Madhya Pradesh	4.37	2.98	2.10	2.38	1.65	3.34	3.51	3.32	3.92
Maharashtra	4.21	6.27	6.60	7.92	9.76	8.71	9.66	10.34	6.61
Uttar Pradesh	5.78	5.02	5.10	3.78	3.09	3.34	3.25	2.71	2.59
All India	24.17	23.09	22.46	27.38	28.61	26.54	30.23	31.34	28.10

Source: Directorate of Economics and Statistics, GoI.

Table 2. Compound annual growth gates of area, production and yield of arhar in major producing states in India (per cent)

Particular	Period	Area	Production	Yield
Gujarat	1990-91 to 2000-01	-1.80** (0.0012)	-4.42 (0.0126)	-2.66 (0.0120)
	2001-02 to 2011-12	-2.43** (0.0033)	2.19* (0.0044)	4.73** (0.0062)
	1990-91 to 2011-12	-2.88** (0.0010)	-1.35 (0.0035)	1.57* 0.0037)
Andhra Pradesh	1990-91 to 2000-01	3.62** (0.0051)	7.62* (0.0139)	3.86 (0.0112)
	2001-02 to 2011-12	1.53 (0.0050)	0.58 (0.0111)	0.94 (0.0094)
	1990-91 to 2011-12	2.64** (0.0018)	5.42** (0.0046)	2.70** (0.0037)
Karnataka	1990-91 to 2000-01	1.89 (0.0072)	6.24 (0.0148)	4.27 (0.0132)
	2001-02 to 2011-12	4.79** (0.0039)	8.36** (0.0119)	3.41 (0.0099)
	1990-91 to 2011-12	3.07** (0.0021)	5.82** (0.0046)	2.68** (0.0040)
Madhya Pradesh	1990-91 to 2000-01	-2.85** (0.0029)	-4.70** (0.0060)	-1.90* (0.0042)
	2001-02 to 2011-12	4.73** (0.0051)	1.27 (0.0086)	-3.31 (0.0103)
	1990-91 to 2011-12	-0.33 (0.0024)	-2.26** (0.0075)	-1.94** (0.0027)
Maharashtra	1990-91 to 2000-01	0.34 (0.0010)	5.13 (0.0116)	4.73 (0.0115)
	2001-02 to 2011-12	1.65** (0.0025)	2.29 (0.0068)	0.63 (0.0054)
	1990-91 to 2011-12	0.74** (0.0007)	3.15** (0.0033)	2.39** (0.0031)
Uttar Pradesh	1990-91 to 2000-01	-2.33** (0.0027)	-1.10* (0.0021)	1.26 (0.0038)
	2001-02 to 2011-12	-2.00** (0.0030)	-4.23** (0.0069)	-2.27 (0.0062)
	1990-91 to 2011-12	-2.49** (0.0010)	-3.80** (0.0020)	-1.35** (0.0020)
All India	1990-91 to 2000-01	-0.30 (0.0013)	0.44 (0.0053)	0.74 (0.0052)
	2001-02 to 2011-12	1.74** (0.0026)	1.89* (0.0040)	0.15 (0.0033)
	1990-91 to 2011-12	0.39* (0.0009)	0.64 (0.0016)	0.24 (0.0015)

Note: ** and *Significant at 1 per cent and 5 per cent levels, respectively. Figures in the parentheses indicate standard error.

RESULTS AND DISCUSSION

The area, production and productivity of tur in India increased considerably in first decade of 21st century (Table 1). Maharashtra occupies first position in tur production, followed by Karnataka and Madhya Pradesh. In 1970s, 1980s and 1990s, Uttar Pradesh was the leading state in tur production in India, but its production was drastically reduced in 2000s. In Gujarat, tur production was meagre till 1970s and increased considerably in 1980s and 1990s then it became stagnant in 2000s onwards. It can be seen from Table 2 that the area, production and yield of arhar in India increased at a lower rate of 0.39, 0.64 and 0.24 per cent per annum, respectively during last two decades (*i.e.* from 1990-91 to 2011-12). Only during 2000s, the area and production increased significantly at the rate of 1.74 and 1.89 per cent per annum, respectively but yield remained stagnant. Karnataka achieved significantly the highest growth rate in area, production and yield of about 3.07, 5.82 and 2.68 per cent per annum, respectively, followed by Andhra Pradesh and Maharashtra. In Gujarat during 1990s the area, production and productivity of arhar decreased by 1.80, 4.42 and 2.66 per cent per annum, respectively. Whereas in 2000s though, the area has declined by 2.43 per cent, the production and productivity increased significantly at remarkable rate of 2.19 and 4.73 per cent per annum respectively. From 1990-91 to 2011-12, though area and production have declined by 2.88 and 1.35 per cent, respectively, the yield has increased significantly at the rate of 1.57 per cent per annum. Thus, Gujarat has achieved the highest growth rate in productivity of arhar among all Indian states in the first decade of 21st century.

Growth in input, output and TFP index

The first set of growth rates in Table 3 is based on three years moving average of indices of inputs, outputs and TPF. The second set is based on annual values. In Gujarat in 1990s the TFP indices was negative, as input indices increased at a higher rate of 1.12 per cent per annum than the output indices (0.72%). Whereas, the annual compound growth rates of total input, total output indices and TFP indices increased at the higher rate of 2.16, 5.06 and 2.84 per cent per annum, respectively in 2000s. In last two decades from 1990-91 to 2011-12 the total input, total output indices and TFP indices of arhar increased at the rate of 0.82, 2.54 and 1.70 per cent per annum, respectively. The contribution of TFP to output growth was high about 67 per cent for arhar in Gujarat. Chand *et al.* (2011) in their TFP analysis of arhar in India, revealed that during 1975-05 the TFP indices for arhar has shown an annual growth rate of 2.18 per cent in Andhra Pradesh followed by Maharashtra 1.0 per cent and in Gujarat 0.85 per cent.

Table 3. Annual growth rate in input use, output, TFP and real cost of production (RCP) for arhar crop in Gujarat: 1990-11 (in per cent)

Period	Input growth	Output growth	TFP growth	RCP growth	Share of TFP in output growth
Based on three- year moving averages					
1990-91 to 2000-01	1.12	0.72	-0.40	0.83	--
2001-02 to 2011-12	2.16	5.06	2.84	0.02	56.11
1990-91 to 2011-12	0.82	2.54	1.70	0.12	66.97
Based on "normal" year values					
1990-91 to 2000-01	1.33	0.67	-0.66	0.60	--
2001-02 to 2011-12	2.12	4.62	2.44	0.01	52.92
1990-91 to 2011-12	0.69	1.71	1.01	0.11	59.15

Note: Normal years excludes years of extreme drought and poor weather: 2000

Table 4. Determinants of TFP for arhar crop in Gujarat (1990-91 to 2011-12) (Dependant variable: TFP index of gram at state level)

Variable	Regression Coefficient	Standard Error	t' ratio	Level of Significance
Model 1				
Constant	4.4033	1.7367	2.5354	--
RES_STOK	0.3197**	0.1017	3.1447	0.0063
EXT_STOK	0.0441	0.0319	1.3939	0.1854
LIT_R	-0.0038	-0.0038	-0.3836	0.7063
NARI	0.2039	0.3680	0.5540	0.5873
INF	-0.4692**	0.0673	-6.9761	0.0000
Adjusted R-Squared	0.9045			
Model 2				
Constant	2.3875	9.0856	0.2628	--
RES_STOK	0.3316*	0.1392	2.3828	0.0384
EXT_STOK	0.0644*	0.0354	1.8200	0.0988
LIT_R	-0.0117	0.0107	-1.0869	0.3026
NPRATIO	-0.2138*	0.0972	-2.1990	0.0525
CI	0.0060	0.0056	1.0612	0.3135
IRR_GW	-0.3790*	0.1746	-2.1708	0.0551
RAIL	0.1492	1.8625	0.0801	0.9377
IRR_INTEN	-0.0020	0.0042	-0.4884	0.6358
IRR_POTEN	0.1445	0.5016	0.2881	0.7791
IRR_CANAL	0.2616*	0.1086	2.4086	0.0368
RAIN	0.1578	0.0989	1.5955	0.1417
Adjusted R-Squared	0.9512			

Note: ** and *Significant at 1 per cent and 5 per cent levels, respectively.
All variables specified in logarithms, except those variables defined in percentage terms.

This reveals that Gujarat has shown an outstanding performance of TFP growth in arhar, though the state is frequently constrained by short of irrigation water due to poor monsoon. The achievement of high growth of TFP (>2.0%) for arhar in Gujarat from 2000s is credited to the release of varieties *viz.,* BDN-2 in 1984, GT-100 in 1992, GT-101 in 2003 and GT-Hy-1 in 2004, by the then Gujarat Agricultural University in the state, remarkably increased the productivity of arhar in first decade of 21st century. This has largely helped to reduce cost of production, although the input prices including labour charges increased remarkably during recent years. Among these released Pigeonpea varieties, BDN 2 and GT 101 were become highly popular among the farmers as these varieties require only 2-3 irrigations after end of the monsoon. Currently, BDN 2 has been replaced by GT 101 and GT-Hy-1. This is clear evidence explained by TFP analysis, that the research expenditure incurred in last three decades for evolving better varieties of arhar crop in the state had played a greater role for increasing productivity, as well as keeping lower cost of production, in the state.

Sources of total factor productivity

A rise in production can be attributed to a growth in inputs or growth in total factor productivity. Productivity growth encompasses changes in efficiency as well as changes in the best practice. As far as sources of productivity change are concerned, the technical change component assumes greater significance. The changes in the variables, that produce growth in TFP, have vital importance to estimate how much each of these sources contributes to the growth of TFP. An attempt has been made to further analysis in terms of contribution of various factors to TFP growth. Estimates of regression coefficients which measure the effect of various sources of TFP, were used to compute elasticity of TFP with respect to research stock and to assess the impact of research has been presented in Table 4. It indicates that government expenditure on agricultural research and education and development of canal irrigation in the state has positive and significant impact on TFP. Besides, rain fall, irrigation potential, cropping intensity and rural infrastructure development assumes a greater role in accelerating productivity in agriculture, particularly for arhar crop in Gujarat. Whereas, effect of balance use of fertilizer, ground water utilization ratio and irrigation intensity were found to be negative, as arhar crop required less fertilizer and few irrigations which were mostly shortfall in poor and erratic rainfall years. From Table 4 it can be further revealed that TFP elasticity with respect to research stock ranged from 0.3197 (model 1) to 0.3316 (model 2) for arhar. The inverse of this elasticity gives research stock flexibility, which represents the required increase in research stock to increase in TFP by 1 per cent. This estimates show that to achieve 1 per cent increase in TFP, the minimum investment in research need to be increased by 3.13 per cent.

Returns to investment on arhar research

The estimated value of marginal product (EVMP) of research investment has been presented in Table 5 revealed that additional investment of rupee one in arhar crop research generated an additional output worth Rs. 14.58 during 1990-91 to 2011-12 in Gujarat.

The internal rate of return (IRR) to research investment for arhar crop of which research stock coefficient in TFP decomposition equation was statistically significant, has been estimated following the assumption given in the methodology section. The result indicated that during the period 1990-91 to 2011-12, the overall rate of return to public agricultural research investment turned out to be 55.50 per cent for arhar crop in Gujarat.

Table 5. Estimated value of MVP and IRR to research investment for arhar crop in Gujarat

Period	Value of marginal product (in Rupees)	Internal rate of return (in per cent)
1990-91 to 2011-12	14.58	55.50

On the whole, the analysis of TFP of arhar crop in the Gujarat shows that it has registered a low productivity growth during the nineties. Vitally increased, during 2001-02 to 2011-12 and registered positively significant moderate growth in TFP throughout last two decades, though it is frequently constrained by moisture stress due to poor and uneven monsoon. This was largely contributed to release of high yielding varieties in the state *viz.*, BDN-2 in 1984, GT-100 in 1992, GT-101 in 2003 and GT-Hy-1 in 2004. Further, the analysis of determinants of arhar TFP indicates that the government expenditure on crop research and extension education, development of canal irrigation in the state and *kharif* rainfall are the important drivers of arhar crop productivity in Gujarat. Returns to investment on arhar crop research have been found to be a highly paying proposition.

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