INDIAN STATE-LEVEL SORGHUM PRODUCTIVITY MEASURES

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This paper has a three fold contribution to the existing literature - 1) Indian state level sorghum input and output data for the period 1970-71 to 2000-01 is collected, 2) non-parametric linear programming productivity measures are estimated, and 3) examine the impact of policy variables like percent of high yielding varieties, percent under irrigation, and herfindahl index of seasonal production (rabi and kharif) on productivity using two way random effects panel model.

Keywords: India, Sorghum, Nonparametric Productivity measures

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Sorghum is one of the main staple food for the world's poorest and most food insecure people. It is known to be cultivated as food grain in Africa and Asia. However, it is popularly grown for feed purposes in developed countries. In India it is the third most widely grown crop after rice and wheat, cultivated during both rainy (kharif) and post-rainy (rabi) seasons. It occupies around 9.5 million hectares especially grown in semi-arid regions of the country producing 7.06 million tons of grain (2002-03). It is grown for dual purpose i.e., food for home consumption and fodder for their livestock.

It is known fact that its area (mainly rainy sorghum) has been on decline during the past three decades. With emerging cash requirements, farmers diversified from traditional mono-cropping to commercial crops like cotton, pulses and oilseed crops. Both profit motivated and consumption driven factors led to this decline. Further, the advances made in productivity mainly through the introduction of high yielding cultivars facilitated the process of commercialization. With the same produce obtaining from much lesser land the area under sorghum (mainly kharif sorghum) was spared to commercial crops, there by resulting in higher farm incomes, and raising their standard of living.

Consumption of sorghum was also on decline over the time. Host of factors like changes in tastes, supply of grains like rice and wheat at a cheaper price (subsidized) through public distribution system (policy related), decrease in sorghum grain quality (especially after the introduction of hybrids) etc. are responsible for the shift away from consumption of sorghum to other fine cereals.

The factors like low profitability of sorghum, less demand as a food grain has not dethered its importance. Farmers still continue to grow sorghum though to a certain minimum level, which can be referred to as household food/fodder security level. Actually up to this level the operations of competition with other crops do not arise. However, above this level sorghum needs to be competitive for it to be included among the various other crops to be cultivated. Recent farm surveys conducted by Dayakar et al (2002) revealed that the demand for fodder in these regions is growing and sorghum continued as a major fodder source (roughage) despite its area decline.

Thus, increase in fodder demand and decline in demand for consumption led to a situation of increase in marketed surplus of grain over the time. The utilization of grain became a major issue as far as kharif sorghum was concerned. Frequent occurrence of grain mold (disease) led to deterioration of its grain quality which compounded the problem of utilization of grain. In view of the above there was a need for creation of demand for alternate uses of sorghum. Sorghum is a potential raw material which can be used in the manufacture of poultry feed, animal feed, alcohol industry, starch etc.

Therefore, its contribution as a continuous input to the industrial sector for processing and value addition is immense. The utilization of sorghum as animal & poultry feed and grain alcohol are more advantageous than starch industry, which has some functional disadvantages, compared to maize and cassava (Tapioca). The annual figures for the year 2001-02 shows that a quantity of 2453 to 2463 thousand tons was absorbed in the industrial sector indicating its demand as a potential raw material for industry. Its export contribution in the same year was 11 thousand tons, all though small indicating its potentiality as an exporting commodity.

However, kharif sorghum finds a niche for industrial purposes like poultry & alcohol industries. However, in wake of recent Government of India's policy to blend petrol with ethanol up to 5% initially, its use would trigger in potable alcohol sector as the present raw material molasses will be then relegated to only bio-fuel sector, sparing potable alcohol for grain sources like Sorghum. In order to gain further ground in poultry industry, its growth in productivity is the key factor which would reduce the cost of production and there by output prices for it to compete with existing raw material like maize.

The growth in productivity varied across the important sorghum growing states. While state like Maharashtra could capitalize these gains, its progress was sporadic in states like Rajasthan. Further, there is a need to decompose the changes in productivity due to introduction of technology or through use of increased inputs.

Its contribution to poverty alleviation in India is by continuous on farm employment and as a source of cheap food. The contribution can be best realized when sorghum is included in the public distribution system by which sorghum will be benefited by the guaranteed markets of government procurement. With this involvement of government in the procurement, in areas where sorghum is produced and preferred staple the people will be benefited via public distribution system and there will be assured market for the crop so as to have a good production frontiers, there by the inclusion of continuous on farm employment for the poor who can be alleviated from the conditions of poverty.

Productivity gains are essential to offset the prospects of continuing food production shortfalls in most semi-arid regions and the prospects of periodic famine in some. Specifically, sorghum will remain a key food security crop as well as will remain important for household food supplies in India. Since most sorghum is still grown by poorer small-scale farmers, investments in research and extension will contribute directly to poverty alleviation. And in most middle and higher-income countries, sorghum will remain important as a feed grain uniquely suited to commercial production in hot, dry and drought-prone regions. However, sorghum importance as food has declined with the availability of finer cereals and owing to a host of factors. This has a serious repercussion on the production and productivity of sorghum in India.

In the present study productivity measures are estimated for each of the eight Indian states producing sorghum by nonparametric linear programming approach using inputs and output data, 1970-2001. The next section describes the nonparametric linear programming approach to estimate productivity measures using output distance functions. The third section details the Indian state level sorghum inputs and output data. The empirical application and results are presented in the fourth followed by conclusions in the final section.

Non-parametric output productivity index

The past decade has witnessed a surge in the application of non-parametric techniques to productivity measurement, due to the ability to handle multiple outputs and inputs, imposes no structural functional form and compute efficiency and productivity measures without the need of prices. In general these methods are distance function approaches that compare the production plans that were available at time *T* with those that were available at time *t*. The productivity change over the interval is typically measured as the proportional increase in output that was achievable at *T* from year *T* inputs, relative to what would have been achievable at *t* from year *T* inputs. Implicit in the estimation procedure is estimation of the piece-wise linear convex production hull that envelops the set of production plans available at either point in time.

The particular non-parametric productivity measure considered here is the output productivity measures described in Shaik; or Färe, Grosskopf and Lovell, Chapter 4 section 1. In this approach, productivity gain between time *t* and time *T* is the proportion by which outputs could have been increased given inputs, in year *T* as compared to year *t*. To formally represent this measure, define the technology using the output reference set satisfying constant returns to scale and strong disposability of outputs:

(1) $$P(x) = \{ y : x \text{ can produced } y \text{ in year} T ; \}$$

A direct measure of productivity gain from year *t* to *T* can then be derived from the output distance function, or its equivalent programming problem

$$(2) \qquad D^T(x^t, y^t)^{-1} = \max_{\theta,z} \{\theta : (x^t, \theta y^t) \in P^T(y^t)\}$$

or

$$\max_{\theta,z} \theta \ \ s.t. \quad \theta y^t \leq Y z \qquad \text{where} \quad Y = (y^1, y^2, \ldots\ldots, y^T)$$
$$x^t \geq X z \qquad X = (x^1, x^2, \ldots\ldots, x^T)$$
$$z \geq 0$$

Thus, examining the year *t* production plan compared with the production possibilities revealed to be available through some future year T, a solution value of θ=1.2 would indicate that 20% more good outputs were observed in year *t*. Hence the interpretation is that the productivity increase between year *t* and year *T* was 20%.

Estimation of the above productivity measure includes estimation of the piecewise linear technology available at time *T*, with the estimated facets consisting of linear combinations of previously observed production plans. For a particular year *t*, the optimal values of *z* represent the linear combination of other years' plans that identify the frontier production facet to which the year *t* production point is projected (along a output arc identified by $(x^t, \theta y^t)$. In (2), *z* is a $\{Tx1\}$ vector of intensity variables with $z \geq 0$ identifying the constant returns to scale boundaries of the reference set. In (2), if *z* is equal to 1, then variable returns to scale boundaries of the reference set is identified.

Individual state level sorghum input and output data are used to estimate sorghum productivity measures for eight sorghum growing states in India.

Next, we examine the impact of policy variables like percent of high yielding varieties, percent acreage under irrigation, and herfinhahl index of seasonal (rabi and kharif) production diversification on productivity. The two-way random effects panel model to examine the impact of policy variables:

$$(3)\ \text{Productivity} = \alpha_0 + \beta_1\ \text{HYV} + \beta_2\ \text{IRR} + \beta_3\ \text{Herfindahl} + \beta_4\ \text{Time} + \varepsilon$$

Output and Input Data

Indian state level sorghum data span a period of 31 years from 1970-71 to 2000-01. Estimated aggregate output and five input Tornqvist-Theil quantity indices for eight sorghum producing states in Indian are used in the analysis. The states include, Andhra Pradesh, Gujarat, Karnataka, Madhya Pradesh, Maharastra, Rajasthan, Tamilnadu and Uttar Pradesh.

The aggregate output Tornqvist-Theil quantity index is computed from sorghum produced during rabi and kharif season. Annual data on sorghum production (yield per hectare times total acres in rabi and kharif sorghum crop) multiplied by prices received by farmers are used in the construction of the aggregate output Tornqvist-Theil quantity index with 1970-71 being the base year. Five Tornqvist-Theil input quantity indices, with 1970 being the base year, are constructed. The inputs include land, farm labor, animal labor, fertilizers and manures.

Empirical Application and Results

Non-parametric productivity indexes for eight sorghum producing states in India are estimated for the period, 1970-71 to 2000-01. Table 1 and 2 presents the productivity measures estimated with constant and variable returns to scale technology respectively. The annual productivity growth rate per year are also presented for 1970-80, 1981-90, 1991-2001 and 1970-2001 time periods. For the time period, 1970-2001 the annual productivity growth rate for the states of Andhra Pradesh, Maharastra, Rajasthan and Tamilnadu are relative close.

Results from Table 1 indicate, productivity gains was experienced over the 31 years time period in Maharastra (312.5), Andhra Pradesh (146.6), Tamilnadu (139), Karnataka (117.3), Uttar Pradesh (112.4), and Madhya Pradesh (105.3) relative to base year of 100. While a decrease in productivity was observed in the states of Gujarat (62) and Rajasthan (24.9). In terms of annual productivity growth rate, Maharastra experienced the highest growth rate (3.433) followed by Andhra Pradesh (1.242), Tamilnadu (1.068). With the exception of Gujarat and Rajasthan, the remaining states experience less than one percent growth rate annually.

Productivity measures estimated under variable returns to scale technology are reported in Table 2. Results from Table 2 indicate, productivity gains was experienced in Maharastra (284.7), Madhya Pradesh (148), Andhra Pradesh (147), Tamilnadu (139), Uttar Pradesh (127), Gujarat (117), and Karnataka (103) relative to 100 for the base year. While a decrease in productivity was observed only in the state of Rajasthan (24.9). In terms of annual productivity growth rate, with the exception of Rajasthan, the remaining states experience positive growth rate.

To examine the impact of policy variables like percentage of high yield varieties used by the producers, percentage of irrigated acreage and the herfindahl index of the seasonal (rabi and kharif) sorghum production form the exogenous variables. The estimated productivity measures form the dependent variable in the two way random effects panel model. The following regression equation was obtained for productivity measures estimated under constant returns to scale (CRS) technology:

$$\text{(4)} \quad \text{Productivity}|\text{crs} = 93.29 + 0.138 * \text{HYV} + 0.068 * \text{IRR} + -3.067 * \text{Herfindahl}$$

The parameter coefficient on high yield varieties (HYV) and irrigated acreage was positive and significant at 10% and 5% level of significance respectively.

Similarly for variable returns to scale technology:

$$\text{(5)} \quad \text{Productivity}|\text{vrs} = 110.058 + 0.172 * \text{HYV} + 0.068 * \text{IRR} + -10.289 * \text{Herfindahl}$$

The parameter coefficient on high yield varieties (HYV) and irrigated acreage was positive and significant at 10% level of significance.

In both the regressions, the herfindahl index reflecting the seasonal (rabi and kharif) sorghum production diversification does not seem to impact the productivity measures.

Conclusions and Implications

This is the first study that estimates nonparametric productivity measures for the eight major sorghum growing states in India. Productivity measures are estimate under constant as well as variable returns to scale technology. Due to the difference in technology identifying the frontier by constant and variable returns to scale, the productivity measures were quite different in few states.   In general productivity measures indicate a positive upward trend across all states with the exception of two states- Rajasthan and Gujarat. The regression analysis revealed the importance of increased use of high yield varieties and well as sorghum acreage under irrigation.

Future research involves fine tuning the data and collect socio-economic variable to better understand the importance of increased sorghum production on alleviating poverty.

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Table 1. Indian State level Sorghum Productivity Measures under Constant Returns to Scale Technology, 1971-2001

Year	Andhra Pradesh	Gujarat	Karnataka	Madhya Pradesh	Maharastra	Rajasthan	Tamilnadu	Uttar Pradesh
1970-71	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**
1971-72	114.6	50.0	99.0	90.8	86.8	74.8	103.0	136.3
1972-73	115.5	63.5	102.9	73.0	83.3	83.5	105.0	108.8
1973-74	123.3	63.5	138.5	81.6	113.9	48.6	106.0	108.0
1974-75	109.7	51.5	96.2	79.6	71.5	45.4	114.0	114.2
1975-76	103.9	66.0	104.8	85.5	88.2	94.3	138.0	100.9
1976-77	97.1	63.5	114.4	107.9	91.7	49.4	105.0	96.5
1977-78	97.1	158.5	98.1	73.7	77.8	83.0	124.0	99.1
1978-79	101.0	113.0	96.2	65.8	69.4	33.7	100.0	108.0
1979-80	126.2	78.5	108.7	95.4	127.1	86.5	110.0	121.2
1980-81	97.1	55.0	138.5	73.0	77.8	27.9	117.0	101.8
1981-82	97.1	50.0	117.3	66.4	70.1	42.9	121.0	88.5
1982-83	159.2	50.0	173.1	68.4	108.3	27.4	122.0	91.2
1983-84	104.9	52.5	110.6	65.8	77.8	66.1	100.0	123.9
1984-85	121.4	113.0	99.0	90.1	147.2	61.6	114.0	116.8
1985-86	106.8	78.5	103.8	67.8	116.0	39.4	117.0	129.2
1986-87	109.7	55.0	112.5	77.6	95.1	24.9	129.0	96.5
1987-88	124.3	50.0	115.4	65.8	97.2	24.9	137.0	100.0
1988-89	97.1	50.0	128.8	73.7	111.8	41.1	185.0	172.6
1989-90	113.6	52.5	102.9	65.8	105.6	28.9	135.0	90.3
1990-91	131.1	50.0	119.2	67.1	112.5	34.7	150.0	133.6
1991-92	97.1	53.5	96.2	105.9	97.9	27.2	114.0	327.4
1992-93	109.7	53.5	103.8	80.9	104.9	32.4	115.0	113.3
1993-94	103.9	55.5	97.1	65.8	102.1	36.7	106.0	99.1
1994-95	129.1	53.0	134.6	99.3	106.9	29.9	100.0	112.4
1995-96	101.0	55.5	108.7	98.0	139.6	53.9	109.0	117.7
1996-97	101.0	90.5	110.6	73.7	129.9	35.7	178.0	131.9
1997-98	109.7	71.5	105.8	114.5	168.8	28.4	124.0	115.0
1998-99	115.5	144.5	151.9	82.2	314.6	39.7	135.0	103.5
1999-00	124.3	64.0	119.2	105.3	243.1	49.1	117.0	238.9
2000-01	146.6	62.0	117.3	105.3	284.7	24.9	139.0	112.4
Annual Average Productivity change per year								
1970-80	2.355	-2.392	0.833	-0.470	2.426	-1.436	0.958	1.945
1981-90	1.582	-0.464	-2.926	-1.038	3.101	0.352	1.441	-1.192
1991-01	1.023	1.975	-0.148	4.178	8.808	-2.949	-0.690	-1.561
1970-01	1.242	-1.530	0.516	0.166	3.433	-4.381	1.068	0.377

Table 2. Indian State level Sorghum Productivity Measures under Variable Returns to Scale Technology, 1971-2001

Year	Andhra Pradesh	Gujarat	Karnataka	Madhya Pradesh	Maharastra	Rajasthan	Tamilnadu	Uttar Pradesh
1970-71	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**
1971-72	116.0	100.0	103.0	110.0	86.7	74.8	102.0	137.0
1972-73	117.0	127.0	105.0	100.0	78.1	83.5	100.0	110.0
1973-74	125.0	127.0	142.0	113.0	121.1	48.6	102.0	112.0
1974-75	112.0	103.0	100.0	112.0	78.1	45.4	110.0	121.0
1975-76	100.0	132.0	109.0	100.0	94.5	94.3	100.0	108.0
1976-77	100.0	127.0	119.0	100.0	78.1	49.4	100.0	100.0
1977-78	100.0	317.0	102.0	102.0	87.5	83.0	122.0	106.0
1978-79	103.0	226.0	100.0	100.0	78.1	33.7	100.0	119.0
1979-80	124.0	157.0	113.0	100.0	117.2	86.5	108.0	131.0
1980-81	100.0	110.0	144.0	108.0	87.5	27.9	116.0	113.0
1981-82	100.0	100.0	122.0	100.0	78.9	42.9	121.0	100.0
1982-83	161.0	100.0	173.0	100.0	121.9	27.4	122.0	102.0
1983-84	101.0	103.0	112.0	100.0	87.5	66.1	100.0	140.0
1984-85	125.0	226.0	100.0	100.0	78.1	61.6	114.0	132.0
1985-86	106.0	157.0	100.0	100.0	95.3	39.4	117.0	146.0
1986-87	112.0	110.0	115.0	100.0	78.1	24.9	129.0	109.0
1987-88	128.0	100.0	111.0	100.0	78.1	24.9	137.0	113.0
1988-89	100.0	100.0	124.0	100.0	112.5	40.9	185.0	191.0
1989-90	117.0	103.0	105.0	100.0	107.0	24.9	135.0	102.0
1990-91	135.0	100.0	100.0	102.0	116.4	29.7	149.0	151.0
1991-92	100.0	105.0	100.0	159.0	95.3	24.9	114.0	370.0
1992-93	109.0	101.0	107.0	100.0	107.0	26.4	115.0	128.0
1993-94	100.0	105.0	100.0	100.0	102.3	24.9	106.0	112.0
1994-95	115.0	100.0	100.0	143.0	110.9	24.9	100.0	127.0
1995-96	100.0	105.0	112.0	140.0	150.8	24.9	109.0	133.0
1996-97	103.0	181.0	108.0	105.0	143.0	24.9	178.0	149.0
1997-98	110.0	135.0	105.0	164.0	184.4	24.9	124.0	130.0
1998-99	116.0	274.0	153.0	114.0	78.1	34.7	135.0	117.0
1999-00	125.0	121.0	109.0	151.0	270.3	45.4	117.0	270.0
2000-01	147.0	117.0	103.0	148.0	312.5	24.9	139.0	127.0
Annual Aver:	Annual Average Productivity change per year							
1970-80	2.174	4.614	1.230	0.000	1.599	-1.436	0.773	2.737
1981-90	1.582	-0.655	-3.109	-0.767	2.035	-1.127	1.528	-1.019
1991-01	0.777	1.438	0.269	3.442	9.393	-1.569	-0.630	-1.561
1970-01	1.251	0.508	0.095	1.273	3.744	-4.381	1.068	0.774