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RESEARCH NOTES

ACCOUNTING FOR PRODUCTIVITY DIFFERENTIAL IN DRYLAND AGRICULTURE: AN ECONOMETRIC EXERCISE

Accounting for differentials of growth of crop output and productivity has been engaging the attention of economists for quite sometime. Two streams of studies could be traced in the literature on this research area. First that involves two distinct production processes which are separated by a given time span. This refers to time-series production analysis. Second, two distinct technologies operating at a given point in time, that is the cross-section production analysis. A number of studies have come to light under the first type,[1] while not many studies have been attempted under the second category.[2] The present study is an attempt to unearth the sources of productivity differentials as between two distinct production technologies in *ragi* enterprise of Karnataka.

METHODOLOGY

The south-eastern and north-eastern belts are the two dry farming regions in Karnataka endowed with different agro-climatic conditions. Bangalore district, falls under the south-eastern belt and has been chosen purposively for the present study. This choice of the region derives support from the fact that the dry farming technology evolved by research has better spread in some areas of this district due to the location of Operation Research Project (ORP) of the University of Agricultural Sciences (UAS) in one of the taluks and the implementation of Intensive Dryland Agricultural Development (IDLAD) project in another taluk, while in all other taluks of the district, no such projects were operating. Samples for the present study were drawn from the above three locations, *viz*., ORP, IDLAD and where there was no such project.

It is believed that such a sample affords much variability with respect to production and employment. The input-output data pertaining to various aspects of *ragi* production were collected through cost accounting-cum-survey method for the years 1977-79.[3] Two sets of data were drawn for the present study. First, keeping the variety constant, to assess the effect of planting technique alone on productivity, pooled[4] data (1977-79) from 70 Broadcasting Local Variety (BLV) *ragi* farms and 127 Transplanted Local Variety (TLV) *ragi* farms were used. Second, the data pertaining to the year 1978-79 from 59 Local Ragi Variety (LRV) farms and 62 Improved Ragi Variety (IRV) farms were used to analyse the effect of variety alone on productivity, keeping the method of planting technique constant. Some

1. Studies based on time-series analysis could be found in Minhas and Vaidyanathan (1965), Minhas (1966), Vidya Sagar (1977), Parikh (1966), Alagh and Bhalla (1979).

2. See Bisaliah (1977).

3. In fact, the data formed a part of larger data collected by the Agro-Economic Research Unit of Dryland Research Unit of ICAR located at UAS, Bangalore. The years chosen for the study were normal. For details, see Deshpande (1984).

4. The hypothesis that the production function parameters of the log-linear regressions fitted separately for the years 1978 and 1979 could not be rejected at any reasonable level of significance. For details of test, see Chow (1960).

of the definitions and limitations of data set need to be more explicit so that the empirical results could be examined in proper perspective. The package of practices such as variety, planting technique, harrowing, weeding and allied intercultural practices associated with each one of BLV, TLV, LRV and IRV *ragi* production is meant to be a proxy for the respective production technologies. Further, both IRV and LRV farms of 1978-79 had used both broadcasting and transplanting sowing techniques. Since the proportions of farms under the two planting techniques were almost the same, the biases, if any, in estimates will be minimal. With this limitation, variety effect has been measured in this study. As indicated earlier, data set on BLV and TLV farms has been used for estimating planting technique effect.

OBJECTIVES

Following are the objectives set out for the present study: (*i*) to develop an econometric model for partitioning the productivity differential between farms using modern technology and those using traditional technology into components of: (*a*) technical change, (*b*) change in the level of capital inputs, and (*c*) change in the level of relative input-output prices; and (*ii*) to test the model so developed empirically, using the dryland input-output data drawn from Bangalore district.

ECONOMETRIC MODEL

According to Ruttan (1957), a given technology can be represented by a unique production function. Further, production function approach lends us a very convenient tool for decomposing a composite entity. So, we represent the two output response functions corresponding to TLV and IRV and BLV and LRV farms by the equations (1) and (2) below:

$$V = V(B, K, Q_F, Q_N, A_K^*, A_F^*, A_N^*) \quad \ldots.(1)$$

$$U = U(b, k, q_f, q_n, a_k^*, a_f^*, a_n^*) \quad \ldots.(2)$$

where, V = gross value of TLV (IRV) response of output in rupees,

B = constant, a proxy parameter for efficiency of production,

K = capital input,

Q_F = fertilizer price normalized by the output price,

Q_N = wage rate of labour normalized by the output price,

A_K^* A_F^* and A_N^* are output response elasticities with respect to capital, price of fertilizer and wage rate respectively. For BLV and LRV function (2), similar definitions of variables hold good.

Observing that every response function[5] has a dual production (profit function), and the estimates of response function bear one to one correspondence with those of production (profit) function, without loss of generality, we can replace, A_K^*, A_F^* and A_N^* by the corresponding production function elasticities, *viz.*, A_K, A_F and A_N in (1) and (2) and then divide (1) by (2) to get:

$$\frac{V}{U} = \frac{V(B, K, Q_F, Q_N, A_K, A_F, A_N)}{U(b, k, q_f, q_n, a_k, a_f, a_n)}$$

With appropriate manipulations, the above equation can be written in the form:

$$\frac{V}{U} = f\left(\frac{B}{b}B - b\right) \quad g\left(\frac{A_K}{a_k}, \frac{A_F}{a_f}, \frac{A_N}{a_n}, A_k - a_k,\right.$$

$$\left. A_F - a_f, A_N - a_n\right) \quad h\left(\frac{Q_F}{q_f}, \frac{Q_N}{q_n}, Q_F - q_f,\right.$$

$$\left. Q_N - q_n\right), \quad i\left(\frac{K}{k}, K - k\right) \qquad \ldots. (3)$$

where f, g, h and i are appropriate functions. Taking natural logarithm of equation (3), on both sides:

$$(\text{Ln } V - \text{Ln } U) = (\text{Lnf} + \text{Lng}) + (\text{Ln } h) + (\text{Ln } i) \qquad \ldots. (4)$$

The left hand side of equation (4) provides us the productivity differential arising from the production of *ragi* under TLV and IRV technology instead of BLV and LRV. Equation (4) partitions this differential into components[6] of technical change (terms in the first bracket), change in the level of relative prices (second bracketed expression) and change in the fixed input level (term in the last bracket).

EMPIRICAL MODEL

In order to validate the model derived above, per hectare Cobb-Douglas production functions[7] were fitted using input-output data collected from the aforesaid TLV and IRV and BLV and LRV farms through cost accounting-cum-survey method during the years 1977-79. The following output response functions of *ragi*

5. Fuss and McFadden (1978).
6. For detailed discussion, see Bisaliah (1977).
7. $Y = AK^{A_K} F^{A_F} N^{A_N} e^E$ is IRV production function.
$y = ak^{a_k} g^{a_f} n^{a_n} e^E$ is LRV production function.

equation (5) for TLV and IRV farms and equation (6) for BLV and LRV farms were derived using the duality principle[8]

$$V = A^{\frac{1}{1-S}} \left(\frac{Q_F}{A_F}\right)^{A_F^*} \left(\frac{Q_N}{A_N}\right)^{A_N^*} K^{A_K^*} \qquad \ldots.(5)$$

$$U = a^{\frac{1}{1-s}} \left(\frac{q_f}{a_f}\right)^{a_f^*} \left(\frac{q_n}{a_n}\right)^{a_n^*} k^{a_k^*} \qquad \ldots.(6)$$

where $S = A_K + A_F$

$$A_F^* = \frac{-A_F}{1-S}$$

$$A_N^* = \frac{-A_N}{1-S}$$

$$A_K^* = \frac{A_K}{1-S}$$

Q_F = price of fertilizer per kg. of plant nutrient derived as the quotient of fertilizer bill and quantities of kg. of plant nutrients consumed at the farm level and normalized by output price.

Q_N = normalized wage rate per hour, defined as wage bill divided by the number of hours of human labour employed per farm.

Y = per hectare value[9] of *ragi* produced under IRV farm in rupees.

K = value of capital services employed per hectare. This includes depreciation charges on dryland equipment[10] and interest charges.

N = number[11] of hours of human labour employed per hectare.

E = a disturbance term which is a random variable normally distributed with mean zero and constant variance.

In fact, the hypothesis that the sum of the output elasticities of per farm production function (using land) amounts to unity could not be rejected at any reasonable level of significance.

8. Fuss and McFadden, *op.cit.* See also footnote 7 for the specification of production functions.

9. Certain row crops such as niger, sesamum, castor, cowpea, field bean, Bengal gram, redgram, blackgram and greengram covering an area of about 20 per cent were also grown in *ragi* plots. The rupee value of these crops is included in Y.

10. These include wooden and iron ploughs, heggunte, tyne hoes, seed drills, etc.

11. Value (in rupees) of labour employed per hectare was also tried for N, with no significant change A_N.

Similar definitions hold good for the variables with LRV response function (6). Dividing equation (5) by equation (6), rearranging the terms with appropriate manipulations, we get the equation counterpart of (4). Comparing this equation with (4), we get:

$$\text{Ln } f = \frac{1}{1-S} \text{Ln} \left(\frac{A}{a}\right)$$

$$\text{Ln } g = \Bigg[A_N^* \text{ Ln} \left(\frac{a_n}{A_N}\right) + \frac{Da_n}{D} \left\{ \text{Ln } a + (1-a_f) \text{ Ln} \left(\frac{a_n}{q_n}\right) + a_f \text{ Ln} \left(\frac{a_f}{q_f}\right) + a_k \text{ Ln } k \right\} + A_F^* \text{ Ln} \left(\frac{a_f}{A_F}\right) + \frac{Da_f}{D} \left\{ \text{Ln } a + a_n \text{ Ln} \left(\frac{a_n}{q_n}\right) + (1-a_n) \text{ Ln} \left(\frac{a_f}{q_f}\right) + a_k \text{ Ln } k \right\} + Da_k \text{ Ln } k / (1-S) \Bigg]$$

$$\text{Ln } h = \Big[A_F^* \; (\text{Ln } Q_F - \text{Ln } q_f) + A_N^* \; (\text{Ln } Q_n - \text{Ln } b_n) \Big]$$

$$\text{Ln } i = A_K^* \; (\text{Ln } K - \text{Ln } k)$$

where $Da_k = A_K - a_k$, Da_f, Da_n are similarly defined.

$D = (1-S) \; (1-s)$, and

$$\text{Ln } V - \text{Ln } U = \text{Ln } fg + \text{Ln } h + \text{Ln } i \qquad \ldots.(7)$$

Equation (7) is obviously the basic partitioning equation proposed in this study to account for productivity differential with the introduction of variety and planting technique.

EMPIRICAL RESULTS

It is clear from Appendix Table 2 that *ragi* production in Bangalore district is governed by non-neutral technical change.[12] So far as varietal change is concerned, technical change appears to be fertilizer and labour-saving.[13] With respect to change in sowing technique, the technical change appears to be capital and fertilizer-saving. Perhaps, it would be worthwhile to postulate various reasons for the lower output elasticity of fertilizer under TLV and IRV farms. The possible explanations could be in terms of low moisture content during the crop season, and less response to fertilizer of soils which are already rich in nutrient content. Since the latter possibility is most improbable in the sample region we propose to elaborate on the first. Could the low fertilizer response of TLV (IRV) farms be attributable to low soil moisture content? To disentangle this controversy it may be worthwhile to take a closer look at disaggregated fertilizer data. The fertilizer input is the aggregate of both farmyard manure (FYM) and chemical fertilizer (urea, etc.).

12. See Hicks (1968).

13. For details, see Bisaliah (1982). The biases identified in this study are only suggestive due to the fact that the effects of factors other than the technology are not captured.

Chemical fertilizer shares a major proportion of composite fertilizer input applied to TLV and IRV farms, but it forms an insignificant, if not zero proportion, in the case of LRV and BLV farms. At this juncture, it may be important to note that even under low moisture conditions, FYM responds favourably, while chemical fertilizers miserably fail. These relationships have been established by studies conducted by Laddha *et al.* (1984) and Pettèrson and Wistinghousen (1979). And perhaps for this reason, LRV and BLV farms have responded well to a major proportion of FYM in the composite fertilizer input while IRV and TLV farms have exhibited least response to a major proportion of chemical fertilizer under the prevailing dryland conditions during the study period. This low response of IRV and TLV farms to fertilizer is reflected in its low partial output elasticities (Appendix Table 1) and in low ratios (0.29 and 0.17 respectively for IRV and TLV farms) of MVPs to fertilizer prices.

The partitioning of differential outputs between the two sets of technologies is presented in Table I. The relevant decompositions are obtained from equation (7) by plugging the mean values of outputs, inputs and their prices and related production function parameters (see Appendix Tables 3, 4 and 1). First, TLV technology has given rise to 23 per cent more output than BLV. A large share of this differential, as much as 35 per cent, is accounted for by technical change alone. This is due to a sizable upward shift of TLV production surface [see col. (3) of Appendix Table 2]. Lower level of capital services employed by TLV technology relative to that of BLV technology has depressed the TLV output by 7.6 per cent. In fact the capital services have been employed very inefficiently on TLV farms, as evidenced by the high ratio of 3.19 of MVP to price.

TABLE I. PARTITIONING OF DIFFERENTIAL OUTPUT INTO COMPONENTS OF TECHNICAL CHANGE, PRICES AND INPUTS UNDER DIFFERENT TECHNOLOGIES

Item	Technology	
	BLV vs. TLV	LRV vs. IRV
(1)	(2)	(3)
Total change in output (per cent)	22.6	44.92
Sources of change		
1. Technical change	35.4	33.39
2. Change due to fixed capital input	—7.6	13.33
3. Change due to relative prices:		
Fertilizer	—1.4	—0.88
Labour	0.9	—2.78
Total change due to prices	—0.5	—3.66
Estimated change due to all sources	27.3	43.08

Note:— Parameter values and mean input levels for computing this table are drawn from Appendix Table 1, Appendix Tables 3 and 4 respectively.

Inasmuch as the farm specific prices for both BLV and TLV technologies are almost the same, the contribution of price component to the productivity differential is negligible. However, the mechanics of partitioning model are illustrated with limited variability in prices.

Second, the variety alone has contributed 45 per cent more output per hectare [see col. (3) Table I]. About 33 per cent of this differential is attributable to technical change. Higher level of capital services used by IRV farms relative to that of LRV farms has boosted the productivity by 13 per cent. The high ratio of 2.13 pertaining to capital input of MVP to price associated with IRV farms is indicative of the fact that the IRV farms could have employed still higher level of capital services and yet derived more profit. The implication of this finding is that intensive use of dryland equipments like ploughs, tyne hoes, heggunte, etc., during pre-sowing and post-sowing periods in terms of land preparation and intercultural practices must receive enough emphasis.

CONCLUSION

The major focus of the present study has been to account for productivity differentials of about 23 per cent with the introduction of new planting technique (*i.e.*, transplanting technique) in local variety *ragi* farms, and of about 45 per cent with the introduction of improved *ragi* varieties in local *ragi* variety farms. For the disentanglement of the total productivity differentials into some meaningful components, an appropriate productivity partitioning model has been formulated, and the mechanics of the model has been illustrated with the analysis of data from dryland dominant Bangalore district. A recapitulation of some of the major findings of the study is in order.

First, the upward shifts in the production function with the introduction of transplanting method of planting and of improved *ragi* varieties have been substantial enough to indicate efficiency gain in production. Further, the technical change that has taken place with the introduction or improved method of planting and of new *ragi* varieties has been indicated to be of Hicks' non-neutral type. This has obvious implications for the demand for inputs and thereby for functional distribution of income.[14]

Second, the study has also indicated that more capital services could be employed profitably on both IRV and TLV farms. The main derivative of this finding is that intensive use of dryland equipments leads to higher productivity on these farms. Lower output elasticities of fertilizer under IRV and TLV technology farms in the study region would call for more detailed agronomic and economic investigations.

Third, the estimated productivity differentials have approximated the actuals in the case of both facets of technical change evaluated in the present study. This lends support to the argument that the productivity partitioning model developed in this study could be effectively used for measuring the contribution of technological and market parameters to productivity growth.

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14. For details, see Bisaliah (1984).

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APPENDIX TABLE 1

PER HECTARE PRODUCTION FUNCTION ESTIMATES FOR DIFFERENT TECHNOLOGIES

Variable	Technology			
	LRV	IRV	BLV	TLV
(1)	(2)	(3)	(4)	(5)
Constant	3.541* (3.92)	5.037* (7.25)	2.521* (3.67)	2.839* (4.00)
Capital	0.107* (3.70)	0.116* (2.24)	0.145* (3.60)	0.091* (4.159)
Fertilizer	0.133** (1.73)	0.026 (0.59)	0.231* (3.99)	0.043 (0.99)
Labour	0.382* (3.66)	0.289* (3.26)	0.417* (4.35)	0.558* (5.83)

* Significant at 1 per cent.
** Significant at 5 per cent.

APPENDIX TABLE 2

TESTING THE DIFFERENCE BETWEEN THE COEFFICIENTS OF PRODUCTIONS BETWEEN RELEVENT TECHNOLOGIES

Variable	Difference between the coefficients	
	LRV vs. IRV	BLV vs. TLV
(1)	(2)	(3)
Constant	1.496* (10.18)	0.3180* (3.0743)
Capital	0.009 (1.20)	—0.0535* (—10.30)
Fertilizer	—0.107* (9.30)	—0.1881* (—23.86)
Labour	—0.093* (5.28)	0.1415* (9.92)

Note:— Numbers in parentheses are computed S. N. Vs.
* Significant at 1 per cent level.

APPENDIX TABLE 3

PER HECTARE GEOMETRIC MEAN LEVELS OF OUTPUT AND INPUTS UNDER DIFFERENT TECHNOLOGIES

Variable	Technology under reference			
	LRV	IRV	BLV	TLV
(1)	(2)	(3)	(4)	(5)
Output (Rs.)	1,517.27	2,199.47	1,407.24	1,725.98
Capital (Rs.)	66.71	128.83	66.80	49.80
Fertilizer (kg.)	209.17	234.85	232.82	198.74
Labour (hours)	1175.68	1117.86	958.48	1367.19

APPENDIX TABLE 4

PER HECTARE GEOMETRIC MEAN LEVELS OF OUTPUT AND INPUT PRICES UNDER DIFFERENT TECHNOLOGIES

Variable	Technology under reference			
	LRV	IRV	BLV	TLV
(1)	(2)	(3)	(4)	(5)
Output (kg.)	1.08	1.08	1.08	1.08
Capital (Rs.)	1.075	1.075	1.075	1.075
Fertilizer (kg.)	1.30	1.64	1.32	1.37
Labour (hours)	0.52	0.57	0.511	0.506

Note:— Price of capital, P_K, is defined such as $P_K K = (1+i/100)$ K where i (=18) is simple interest chargeable per Rs. 100 per annum. The farm enterprise is supposed to bear interest for five months, which happens to be the length of crop season.

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