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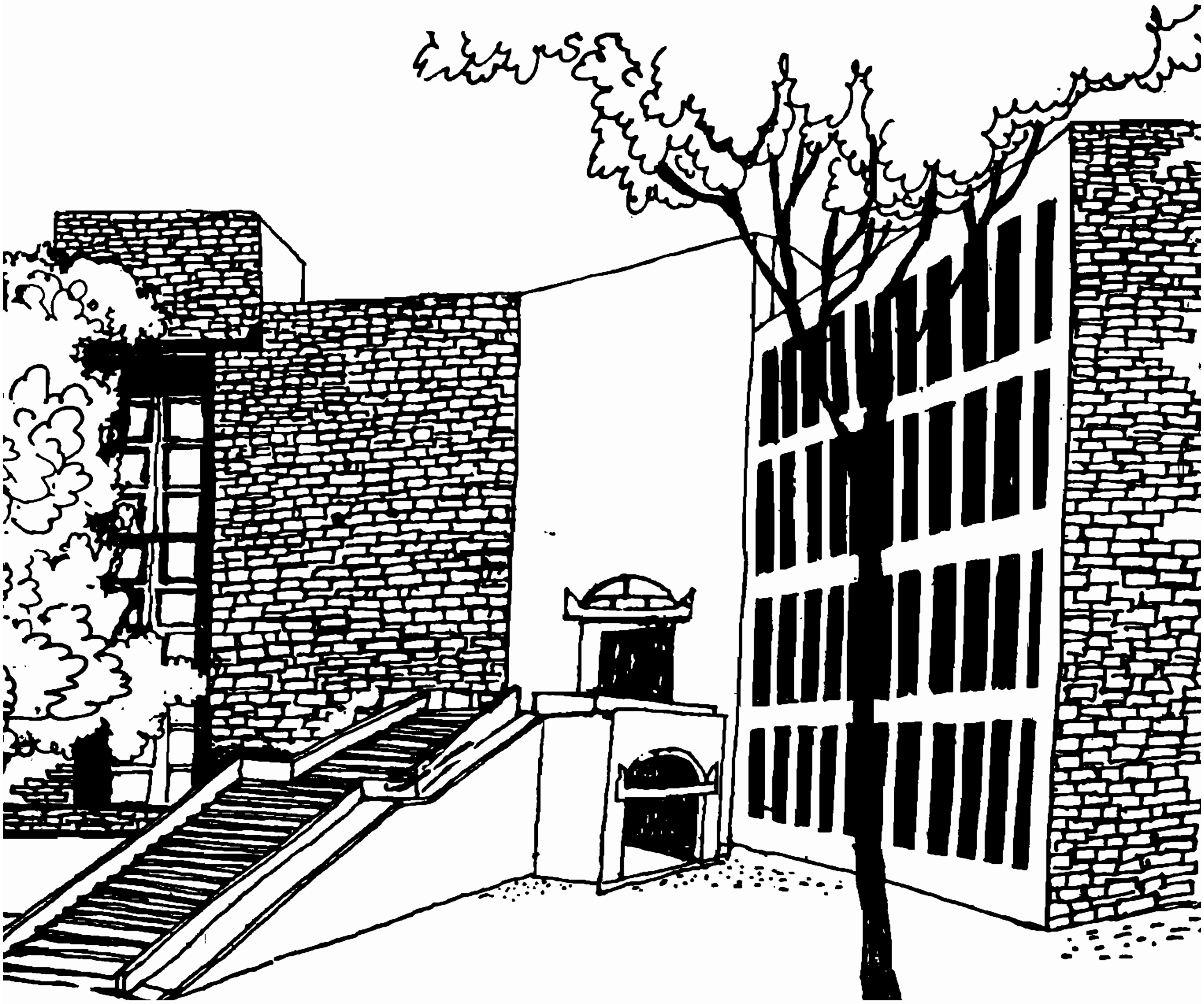

DETERMINANTS OF TOTAL FACTOR PRODUCTIVITY IN INDIAN AGRICULTURE

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Determinants of Total Factor Productivity in Indian Agriculture

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Preliminaries

Growth in total factor productivity (i.e. technical change) in agriculture is both a necessary and sufficient condition for its development. It is a necessary condition because it enables agriculture to avoid a trap into Ricardo's Law of Diminishing Returns to which the sector is more prone. And it is a sufficient condition because it increases production at reduced unit-costs/prices in real terms (for some evidence, see Kahlon and Tyagi 1983, Sidhu and Byerlee 1992, Kumar and Mruthyunjaya 1992, Rao 1994, Kumar and Rosegrant 1994, Singh, Pal and Morris 1995, and Acharya 1997). Question therefore arises what determines technical change in agriculture.

Studying this question would facilitate making a distinction between agricultural strategy and policy instruments to achieve it which has not been clearly recognized by the policy-makers nor by the earlier literature to an extent. It would also aid more informed decision making in identifying policy priorities for technical change. These are especially required because former Finance Minister and present Finance Secretary in the wake of economic reforms have argued that improvement in terms of trade consequent upon reducing protection to industry and trade would provide better incentives for

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investment and technical change in agriculture (see, Singh 1995, and Ahluwalia 1996). But the earlier studies show that technical change is influenced by non-price factors like government investment in agricultural research, education, extension, and infrastructure like rural roads, regulated markets, etc. (see, for example, Jha and Evenson 1973, Rosegrant and Evenson 1994, and Kumar and Rosegrant 1994). This paper considers both price and non-price factors to understand the process of change in total factor productivity considering the period from 1966-67 to 1989-90 for which the required data are available.

Before presenting an analytical framework and its application for studying this, it must be stated that among the three agricultural strategy options of extensive farming, intensive agriculture, and technical change it is this change which is universally accepted as the best strategy (Desai 1997). This raises three issues of nature of technical change, its measurement, and its contribution. These are briefly reviewed by drawing on the scant literature that uses more convincing framework.

Nature, Measurement and Contribution of Technical Change

Technical change is invariably embodied in new inputs like HYV seeds, fertilizers etc., and services like appropriate timing and method of their application (for some illustrations on this, see Desai and Namboodiri 1997a). The former represents new physical inputs, while the latter represents scientific knowledge. Ideally, therefore, technical change should be defined as growth in output associated with both of these. But separate data on most new inputs such as HYV seeds, irrigation-water by new methods (like more efficient pumping devices and canals with drainage and on-farm development) etc. are rarely available. Though the data on fertilizers and pesticides are available they cannot be separately considered to capture their impact in terms of technical change as they are also complementary to HYVs, irrigation-water etc. (Mellor 1966). Thus technical change in practice is defined as growth in output that is not accounted for by the growth in all inputs. In other words, residual productivity growth is termed as technological change and it is attributed to scientific knowledge i.e. R&D. This is also known as total factor productivity (TFP) growth since it postulates increases in total output less increases in total (all) inputs (see, for example, Abramovitz 1956, Dension 1962, and Hayami, Ruttan and Southworth 1979). This implies an upward/downward shift in production/cost function and hence it represents efficiency growth.

Technical change so defined is studied in earlier literature that has three heroic assumptions. One, it assumed perfectly competitive product and factor markets. Two, it considered technical change to be Hicks-neutral i.e. relative payments to factors of production are unbiased. And three, technical change is disembodied (see, for example, Solow 1957, Jha and Evenson 1973, Evenson and Kislev 1975, and Dholakia and Dholakia 1993). More recent literature, however, does not make any of these restrictive assumptions (Sidhu and Byerlee 1992, Kumar and Mruthyunjaya 1992, Kumar and Rosegrant 1994, Rosegrant and Evenson 1994, and Desai 1994). Underlying the approach in this literature that follows Christenson (1975) and Diewert (1976) is a translog production function. This production function allows for non-constant as well as constant returns to scale, complementarity so unique to agricultural production process[1], and operation of imperfect markets.

Diewert (1976) derives Tornquist-Theil Index of TFP from the translog production function. This index is computed as the ratio of an index of aggregate output to an index of aggregate inputs. In logarithmic form this index is

$$\ln (TFP_t / TFP_{t-1}) = ½ \textstyle\sum_j (R_{jt} + R_{jt-1})$$

$$\ln (Q_{jt} / Q_{jt-1}) - ½ \textstyle\sum_i (C_{it} + C_{it-1})$$

$$\ln (X_{it} / X_{it-1})$$

where

R_j = Per cent share of output j in total revenue

Q_j = Output j

C_i = Per cent share of input i in total cost

X_i = Input i

all are in period t and t-1.

Earlier stated five studies which use this index-based method include two studies on wheat (namely, Sidhu and Byerlee 1992, and Kumar and Mruthyunjaya 1992), one on rice (namely, Kumar and Rosegrant 1994), one on major crops-sector as a whole (namely, Rosegrant and Evenson 1994), and one on agriculture and allied sectors excluding forestry (namely, Desai 1994). While the three studies on two crops consider nine farm inputs, namely, seed, manure, fertilizers, pesticides, human labour, animal labour,

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[1] When this condition is satisfied the output response is larger than the sum of effects of each individual input used singly (Ishikawa 1967).

machine labour, irrigation, and land, the study on major crops-sector considers seven inputs of fertilizers, tractors, tube-well irrigation, irrigated land, unirrigated land, human labour, and animal labour. The former uses cost of cultivation data for the post-Green Revolution period from 1968/70/71 to 1989 for some states, while the latter uses the data for 1957 to 1986 for 271 districts covering 13 states in India.

The remaining study (Desai 1994) on agriculture and allied sectors excepting forestry is most comprehensive in its input coverage that includes eleven farm inputs that are both credit and self-financed, namely, land, labour, seeds, organic manure, fertilizers, pesticides, diesel, electricity, irrigation charges, private and public capital (that consists of land improvements, farm equipments and tools, public and private irrigation, agricultural machinery, farm houses, livestock, and inventories).[2] The sources of data for these are National Accounts of Central Statistical Organization (CSO) and Dholakia and Dholakia 1993. The period covered is 1950-51 to 1989-90. This study is utilized for the purpose of analysis addressed in this paper.

Finally, **Table 1** reports the absolute and relative contributions of growth in inputs and TFP from the sector-wide studies by Rosegrant and Evenson 1994, and Desai 1994. While the former shows that little over 50 per cent of growth in crop-output is contributed by technical change,

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[2] **While labour cost is for agriculture rather than crops alone, feed for livestock is not considered as crop by-products are not included in the value of outputs. Some items of costs like veterinary charges, feed for fish, etc. are not considered due to non-availability of data. For details on methodology of constructing Tornquist-Theil Index of TFP, see Desai 1994.**

the latter estimates that close to 38 per cent of growth in output of agricultural and allied sectors is accounted for by technical change. This lower estimate of relative contribution of technical change may be because this study is more comprehensive in its inputs coverage. Moreover, technical change has not been so important in allied sectors of dairying and fisheries which account for about 30 per cent of agricultural production. Both the studies, however, show that the contribution of technical change in post-Green Revolution (GR) is much higher. They further show deceleration in total factor productivity in later period of Green Revolution (see **Table 1**). Both the studies conclude that Green Revolution type of technical change is land, labour, and intermediate inputs with complementary capital augmenting. Indeed, employment elasticity in agriculture during post-GR was 1.37 per cent as against only 0.52 per cent prior to GR.

Conceptual Framework, Methodology and Data Base

As stated earlier, technical change is influenced by price and non-price factors. While the role of price incentives to induce technical change is obvious, that of non-price factors arises from the shifts in structural change in agriculture. These shifts could be from (1) antiquated to modern scientific knowledge-based farming, (2) isolated farms to those integrated with the rest of the economy, and from (3) oppressive to egalitarian land tenure system (Dantwala 1967 and 1970). Three broad policy instruments that would facilitate these shifts are government expenditure on R&D, farm inputs and credit, institutional infrastructure for access to product, inputs and credit markets, and land reforms, respectively. Considering the available data the first one is approximated by government expenditure on agriculture research and education, and crop production programme (GERD), P_2O_5 to N fertilizer consumption ratio (PNR), share of canal irrigated area (CIS) and rural literacy ratio (RLR). Infrastructure for the access to various markets is approximated by the density of regulated market yards, fertilizer dealers and field-offices of rural financial institutions (MBID), and density of rural roads (RRD). And Gini ratio of distribution of owned land (ONLE) and that of operational land (OPLE) are surrogates for egalitarian land reform measures.[3]

Barter terms of trade (BTOT) represents the price factor, while annual average rainfall (ARF) is an important determinant of technical change for an agriculture whose fortunes are dependent on weather Gods. Thus, the multi-variate model that may explain behaviour of technical change is

$$TFP = f\ (BTOT,\ GERD,\ PNR,\ CIS,\ RLR,\ MBID,\ RRD,\ ONLE,\ OPLE,\ ARF)$$

Each of these determinants is discussed to identify how it influences growth in TFP and what is the nature of its relationship with TFP i.e. positive or negative, a priori.

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3 Fragmentation of land is also an eligible factor for explaining technical change. The larger the number of fragments per holding /farm lower would be the growth in TFP. But it may also reduce the risks and uncertainty in farming and thereby may induce this growth. Depending on which of these two impacts is larger the aggregate impact on technical change could be $> = <$ 0. Although this could not be studied due to non-availability required data, land consolidation must be accorded the highest priority among all land reforms.

Barter Terms of Trade (BTOT): Prices received (P_R) by farmers for the sale of their products and prices paid (P_P) by them to purchase farm inputs and consumer goods is defined as barter terms of trade. This is measured as composite index of P_R to that of P_P. Under the new economic environment that reduces protection to trade and industry the prices paid (P_P) by farmers may decline. Moreover, it may provide new trade opportunities. While the former would directly improve barter terms of trade (BTOT), the latter would encourage it indirectly through product innovations. Both of these would provide an incentive to the farmers to innovate in methods of farming and in enterprise-mix and thereby improve TFP. In other words, BTOT is positively associated with TFP. But as BTOT increases farmers incomes also rise with consequent increase in their consumption leading to decline in investment in acquiring new knowledge through, say, adult literacy, contacting extension worker, and visiting demonstration farms, agricultural fairs and farm university. Thus, BTOT and TFP are inversely related. A priori, therefore, the effect of BTOT on TFP could be > = < 0. This suggests that what protagonists of economic reforms argue is just one of the three possible outcomes of improvement in BTOT. Which one of these three holds is an empirical question which they have not analysed. The data for BTOT are drawn from Thamarajkshy 1969 and 1994.[4]

Government Expenditure on R&D (GERD): That R&D is a corner-stone for growth in total factor productivity is undisputed.

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[4] While these studies construct BTOT by considering wholesale prices for prices received (P_R) by farmers, Mungekar 1997 constructs BTOT based on farm harvest prices. But the results based on this latter study remain unaltered. Since the estimated model based on the former studies has better statistical properties data from them are utilized.

Government expenditure for R&D in agriculture is also unquestionable because it is a public good in whose case market fails and/or works imperfectly. This is especially so for biological and chemical technologies. Although there is some growth in R&D expenditure of some private (seed) companies it is insignificant and mainly for hybrids rather than self-pollinated crops which are more commonly grown. Moreover, these companies depend on public R&D for developing their R&D (Singh, Pal and Morris 1995; and Singh and Asokan 1997). Thus, government expenditure on agricultural research and education, and crop production programmes is considered as GERD. While the former represents building R&D activities and capacities, the latter represents technology transfer services. Both these expenditures are considered together as separate data on them are not available for sufficiently long period of 1966-67 to 1989-90. These expenditures are in 1980-81 prices which were derived by using CSO's agricultural NDP deflator. Moreover, they are cumulated as expenditure on R&D in any one year has an effect over a period of time. A lag of five years is assumed as in other studies (see, for example, Kumar and Rosegrant 1994; Rosegrant and Evenson 1994; and Jha and Evenson 1973). A priori it is expected that TFP and GERD are positively associated. Data on GERD are derived from Indian Agriculture in Brief published by the Directorate of Economics and Statistics of the Ministry of Agriculture.

P_2O_5 to N Fertilizer Ratio (PNR): While use of all fertilizers is considered as a part of all inputs in constructing TFP index, this ratio is considered to influence TFP proper for two reasons. One, fertilizers being one of the leading inputs in agriculture (Ishikawa 1967) it requires wide variety of appropriate government policies for this input (industry). And two, balanced application of N and P fertilizers is more important in inducing growth in TFP. This latter concern has acquired added significance since the prices of P unlike N fertilizers have been decontrolled in the wake of new economic environment. It is expected that the TFP growth will directly change with the PN ratio. Data on this ratio are collated from Fertilizer Statistics published by the Fertilizer Association of India.

Share of Canal Irrigated Land (CIS): Irrigation is yet another leading input in agriculture (Ishikawa 1967). Canal irrigation being a public good requires government expenditure. While this public investment is considered as a part of all inputs in constructing TFP index, its incentive effects that farmers would have may be captured by considering its share in total irrigated land. Such effects can induce farmers to be more scientific in their farming and consequently this share should have positive influence on the growth of TFP. Since more than three fourth of farmers have less than 2 hectare farm size, these incentives of canal irrigation are very important. The data on irrigated land by sources of irrigation are collated from the earlier stated Agriculture in Brief.

Rural Literacy Ratio (RLR): That literacy would enable farmers to improve efficiency of farming is obvious for it would enable them to be more scientific in the application of various (new) inputs. The data for RLR are derived from the Population Census of 1961, 1971, 1981, and 1991. For the intervening years this percentage is interpolated, since it being a structural variable.

Marketing and Banking Infrastructure Density (MBID): This institutional infrastructure density is crucial just not only for providing physical inputs but also for inducing incentives for technical change. This is because it enables farmers to substitute traditional channels by new ones that provide new (efficient) services besides being non-extortionist. Moreover, institutions providing this infrastructure also promote technical services that would make agriculture scientific knowledge driven. Data on the number of regulated market yards, fertilizer dealers, and field-offices of rural banking are drawn from Statistical Abstract of India, Fertilizer Statistics, and Statistical Statements relating to Co-operative Movement in India and published by the RBI and NABARD.

Density of Rural Roads (RRB): This density opens up the isolated and closed villages both for the farmers and agencies serving them. The improved communication has an incentive effect not only in physical sense but also in terms of receptivity of farmers to improve their knowledge which would act like a spring-board to improve total factor productivity. The data on panchayat and block road length are collated from Statistical Abstract of India.

Gini Ratio of Distribution of Own Land (ONLE): The inverse relationship between productivity and farm-size in Indian agriculture is widely acclaimed. This is mainly due to smaller farmers' labour endowment over which they have better command in making farming more careful husbandryoriented. It is also because larger farmers have diseconomies in managing larger labour force. Moreover, scale economies in general are insignificant in agriculture. Thus, it is expected that the growth in TFP is inversely related to inequality in land ownership distribution. While this may be its labour management related effect, it is likely that this inequality may enable larger farmers to have greater access to knowledge as an input and thereby TFP may be directly related to it. A priori, therefore, influence of ONLE would be > = < 0. While this may hold at the aggregate level it is important to note that these two effects (i.e. labour management related efficiency and scale related efficiency) could be different for small farmers compared to larger farmers. In the case of smaller farmers the labour management efficiency could be positive (i.e. > 0), though the scale effect could be negative (i.e. < 0) as their access to new knowledge and ability to take risk could be lower. But, exactly the opposite may hold in the case of larger farmers. Data on Gini ratio of land ownership distribution for 1961-62, 1971-72, 1982, and 1992 are obtained from Thorat 1997 and Sharma 1997 and for the intervening years they are interpolated.

Gini Ratio of Distribution of Operational Land (OPLE): Operational land is owned land plus lease-in land minus lease-out land and hence it enables studying tenancy in agriculture. Since the data on extent of tenant cultivated land are unsatisfactory on account widespread prevalence of oral and concealed tenancy the Gini ratio of distribution of operational land is considered. These data are drawn from Sharma 1997 and Thorat 1997 for 1961-62, 1971-72, 1982, 1992 and for the intervening years they are interpolated. Even this inequality is expected to have either positive or negative impact on TFP (i.e. > = < 0) for the reasons discussed earlier.

Average Annual Rainfall (ARF): Since technical change is measured as residual growth in productivity any fluctuation in production would also be applicable to this productivity. Agriculture being largely rainfed this fluctuation in TFP could also be determined by average annual rainfall.

Table 2 provides mean, standard deviation, and annual compound growth rate of TFP and its ten determinants for 1966-67 to 1989-90.

The above discussed multi-variate model explaining behaviour of technical change is estimated by Ordinary Least Squares method. Both linear and double log form of function were considered. Since the statistical properties such as R bar square, `t' values, and D-W statistic are better for the double log form of the model the next section analyses its results.

Analysis of Results

Three major features of the results are discussed. These are their statistical properties, signs of the estimated coefficients, and relative importance of various determinants of total factor productivity. Study of this importance is extremely crucial for it would facilitate prioritising various determinants and thereby enable identifying policies that would be more conducive to accelerating technical change in agriculture. **Table 3** reports the estimated model.

As much as 98 per cent of the variation in total factor productivity is explained by the specified model. This R bar square is statistically highly significant. Durbin-Watson statistic reveals that there is no autocorrelation. Eight of the ten determinants of total factor productivity have statistically significant `t' ratios (see **Table 3**).

The sign of the regression coefficient associated with the barter terms of trade (BTOT) is negative. Similar finding is reported by Kumar and Rosegrant 1994 and Rosegrant and Evenson 1994 though they do not explain why this is so. This finding suggests that the positive incentive effect of the relative farm prices is more than offset by its negative impact through the reduced farmers' investment in acquiring new knowledge because of increased consumption resulting from rise in income associated with these prices. It further indicates that the simplistic interpretation of the impact of relative prices on technical change which seems to guide current agricultural policy should be avoided forthwith.

Only two out of the remaining nine explanatory factors have a sign that is contrary to a priori expectation. This is so for the share of canal irrigated area (CIS) in total irrigated land (see row 4 in **Table 3**). This negative association could be because canal irrigation is known to be inefficiently managed. Such a perception also holds for the canal commands which generate electricity. Both the supplies of canal water and electricity being inefficient they fail to act as an incentive to farmers in making agriculture technologically vibrant. Such a nature of these supplies needs to be corrected by both appropriate pricing and better management that could be jointly organized with the farmers.

Another variable with a sign that is contrary to expectation is rural literacy ratio (RLR). This may be because a better measure such as number of years of schooling of farmers could not be used due to non-availability of data. In any case this coefficient is statistically non-significant (see col 3 in row 5 in **Table 3**).

Between the two land distribution variables the one for land ownership (ONLE) shows that as inequality in this distribution increases the TFP decreases. In other words, as this inequality reduces the TFP increases (see rows 8 and 9 in **Table 3**). A possible explanation for this runs somewhat as follows.

The positive labour management related efficiency of the smaller farmers has more than offset negative scale effect arising from their lower access to new knowledge and risk-taking ability. This has dominated at the "mean level" to more than outweigh the possible positive scale effect of larger farmers' greater access to new technology and higher risk-taking ability that may outweigh their negative labour management related inefficiency. Alternatively, the former is reinforced by larger farmers' labour-endowment related inefficiency outbidding the positive scale effect arising from their greater access to new technology and ability to take risk.

Thus, egalitarian land ownership related reform would improve total factor productivity. This is quite consistent with the well-known phenomenon of smaller farmers being more efficient as well as Green Revolution type of technical change being scale-neutral, divisible, and land and labour augmenting. But all this cannot be said about the relation between TFP and inequality in distribution of operational land (OPLE) which is positive.

In other words, smaller tenant unlike owner farmers are inefficient. This is perhaps because tenancy is prohibited in many states, besides its reforms are neither formulated properly nor are they enforced effectively (see, for example, Datta and Desai 1997). Such uncertain and inappropriate land lease environment obviously cannot provide the incentives for efficiency of the smaller farmers who are the main lessees in tenancy market (Sharma 1997). This result of positive "net" impact of inequality in operational land distribution may also be perhaps due to larger tenant farmers having greater access to new knowledge leading to positive scale effect more than outweighing the negative impact arising from their inefficiency in managing larger labour force.

The relative importance of various explanatory factors is shown in col 4 in **Table 3**. This is obtained by the standardized regression coefficients ignoring signs. Such coefficients are given by βi X (standard deviation of explanatory variable Xi ÷ standard deviation of the dependent variable Y). They are utilized because of differences in the measurement of different variables (Snedecor and Cochrane 1967). Following findings are highlighted.

One, between the price and non-price factors it is the latter that is more important in inducing technical change in agriculture. Thus, contrary to the official view non-price policies have greater role to play in achieving rapid technical change.

Two, the single most important determinant of total factor productivity is the government expenditure on agricultural research, education and extension (GERD) (see col 4 in **Table 3**). Indeed, this variable alone explains as much as 87 per cent of the total variation accounted for by the estimated model.

Three, the next most important determinant is the Gini ratio of distribution of operational land (OPLE). Truly, it is even more important than the inequality in land ownership distribution. This suggests that between the two land reforms of tenancy, and land ceiling and redistribution, it is the former which must be prioritised (for similar conclusion see Datta and Desai 1997). Moreover, it also suggests that selective liberalization of tenancy would be more healthy to remove the earlier discussed deficiencies of the lease market for accelerating technical change. Registration of rights of tenants, protection from eviction at will, and minimum period of lease may be legislated by the state. But other terms and conditions of tenancy may be left to the lessees and lessors although it might be desirable for the state to restrict their choice about the nature of rent in terms of fixed rent or crop plus cost share.

Four, rural literacy ratio (RLR) is the third most important factor, while reducing the inequality in ownership of land (ONLE) is the next most important determinant. The former suggests the important role of rural education for promoting technical change though this should be in the nature of more functional professional literacy. And the latter may be interpreted to suggest that existing land ceiling and redistribution policies which have not been seriously implemented must be first pursued vigorously to enhance growth in total factor productivity (for similar policy recommendation of a national seminar, see Desai 1997). Radical ceiling on ownership of land is not suggested because available surplus land (both in amount and quality) from larger farmers may not be sufficient to meet the demand of those land hungry. Moreover, such a ceiling may take away land from medium size peasantry who are more productive and hence it may lead to egalitarian stagnancy rather than growth.[5]

Five, next policy priority seems to be for improving density of rural roads (RRD) followed by improving marketing and banking infrastructure density (MBID).

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[5] In 1992 landless and land-owning marginal farmers (upto 1 ha), and small farmers (1.01 to 2 ha) were, respectively, 13.09 mn, 70.57 mn and 15.62 mn, while the land owned by large farmers (more than 10 ha) was 16.23 mn ha (Sharma 1997). Even considering 30.60 mn ha of land owned by medium farmers (4 to 10 ha) the land available for redistribution would be inadequate since neither the former nor the latter category of farmers could be made landless assuming that radical redistribution is socio-politically and administratively feasible. Moreover, these larger farmers are mainly in semi-arid and arid areas which have much less developed agriculture.

Six, though influencing relative prices (BTOT) for agriculture is more important than either P to N fertilizer ratio (PNR) or the share of canal irrigated land (CIS) these two input related changes may be prioritised considering that the former as stated earlier, has a detrimental impact on technical change. For improving canal irrigation the earlier discussion needs no further emphasis. But the improvement in P to N ratio may be promoted through more rationalized prices for these two nutrients as well as more sharply focused research and extension services that emphasize both seed and resource-centered rather than only seed OR only resource-centered new technologies (for some details on this see Desai and Namboodiri 1997a; and Desai 1997).

We now report marginal internal rate of return (IRR) on government expenditure on R&D (GERD). Estimation of this IRR first requires knowing value of marginal product (VMP) of this expenditure. This is given by the elasticity of GERD multiplied by the mean of production attributed to this expenditure divided by the mean value of this investment.

In other words,

$$\text{VMP of GERD} = \text{Coefficient for GERD} \times \left[\frac{\text{Mean value of agril. prodn.} \times \text{Relative contn of TFP}}{\text{Mean of GERD}} \right]$$

This works out to Rs.1.09 i.e. for every 1 Rupee of additional government expenditure on R&D the value of marginal agriculture product is Rs.1.09. This is just not one shot benefit. It results into a stream of benefit over a period of time. Assuming that this benefit of investment made in period t-i will start generating a benefit after a lag of five years, this benefit will accrue at an increasing rate in next nine years, remain constant next another nine years and thereafter it will start declining.

Considering the time weight estimated by Evenson and Pray 1991 and reported in Kumar and Rosegrant 1994, the investment of one rupee in year t-i will generate benefit equal to 0.1 VMP in year t-i+6, 0.2 VMP in year t-i+7... so on, and it will be 0.9 VMP in year t-i+14. After which the benefit will be equal to VMP upto t-i+23. Then the benefit for year t-i+24 onwards will be equal to 0.9 VMP and in t-i+25 it will be 0.8 VMP and so on. Now considering the investment of Rupee 1 in zeroth year and discounting it together with this benefit stream at the rate `r' at which net present value becomes zero will give the marginal IRR. In our case this works out to 21 per cent (to be precise 20.51 per cent). This is quite well comparable to the national parameter of both social discount rate of 8 to 12 per cent and investment rate of discount of 15 to 20 per cent. Incidentally, this return should not be interpreted as accruing to farmers nor to any (private) entity investing in agricultural research and extension.

Summing-up

This paper departs from the earlier literature on technical change in agriculture in advocating three major conclusions.

One, technical change is a superior strategy compared to either extensive farming or intensive agriculture as it unlike the other two options, increases production at reduced unit-costs/prices in real terms which benefit the poor most. Moreover, it is agro-economically most sustainable. Though achieving technical change is complex it could be organized by combining the role of agricultural research and extension with location-specific farmers own knowledge as this service alone explains as much as 86/87 per cent of variation in total factor productivity in post-GR period. Thus, current under-investment of the government in agricultural R&D[6] must be corrected on a priority basis. This would fetch handsome dividend as marginal return on such investment is over 20 per cent.

Two, measurement of technical change based on a framework that allows this change to be (a) embodied in new inputs and services, (b) complementary, (c) non-neutral as well as neutral in its factor rewards, and (d) achieved under imperfect markets is superior.

And three, there is a need for policy paradigm shift from "techno-mechanical" approach revolving around price fundamentalism as is now/input response function as was the case earlier to "behavioural" approach in which central place is assigned to non-price factors of R&D and agricultural infrastructure, rural infrastructure, and land reforms.[7] This follows from two findings. One of these is that technical change is most influenced by government

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[6] In early 1990s this was 0.43 per cent of agricultural GDP as against internationally recommended norm of 2 per cent (Pal Singh and Jha 1997).

[7] This is in addition to the policies for new farm inputs such as seeds, fertilizers, pesticides, irrigation , farm implements and machinery, and electricity.

expenditure on R&D, followed by liberal tenancy regulation, rural literacy, land redistribution through existing ceilings, rural roads, marketing and banking infrastructure, and balanced use of fertilisers combined with efficiently managed canal irrigation in that order of importance. And two, relative farm prices have deleterious ramifications to technical change process and as a result it has a secondary and neutral but not passive role. Such a role is even consistent with what is recommended by some past literature that has shown its such impacts for poverty, aggregate agricultural supply, industrial costs, government expenditure on agriculture, and economic growth in general (see, for example, Dantwala 1967, 1970, and 1986; Desai 1986; Mellor 1968, 1976, and 1978; Rangarajan 1982; Mungekar 1992; and Desai and Namboodiri 1997b and 1997c).

Table 1
Annual Growth Rates in Output, Inputs and Total Factor Productivity (TFP)

Rosegrant and Evenson 1994				Desai 1994			
Periods	Crop Output	Crop Inputs	TFP	Periods	Agril. Output	Agril. Inputs	TFP
1957-67	2.18 (100)	1.08 (49.54)	1.10 (50.46)	**Pre-GR** 1950-51 to 1965-66	2.05 (100)	1.49 (72.68)	0.56 (27.32)
1967-76	2.68 (100)	1.28 (10.45)	1.39 (89.55)				
1976-86	2.07 (100)	1.00 (48.31)	1.05 (51.69)	**Post-GR** 1966-67 to 1989-90	3.41 (100)	1.96 (57.48)	1.45 (42.52)
Entire i.e. 1957-86	2.25 (100)	1.11 (49.33)	1.13 (50.67)				
				1966-67 to 1973-74	1.98 (100)	1.14 (57.58)	0.84 (42.42)
				1974-75 to 1979-80	4.25 (100)	2.54 (59.76)	1.71 (40.24)
				1980-81 to 1984-85	3.68 (100)	2.29 (62.63)	1.39 (37.77)
				1985-86 to 1989-90	4.49 (100)	3.16 (70.38)	1.33 (29.62)
				Both i.e. 1950-51 to 1989-90	2.97 (100)	1.85 (62.29)	1.12 (37.71)

Figures in brackets are relative contributions of inputs and TFP in output growth.

Sources: Adapted from

(1) "Total Factor Productivity and Sources of Long-term Growth in Indian Agriculture", Mark W. Rosegrant and Robert E. Evenson, paper prepared for IFPRI/IARI Workshop on Agricultural Growth in India, May 1-6, 1994, New Delhi, India.

(2) "Contributions of Institutional Credit, Self-finance and Technological Change to Agricultural Growth in India", Bhupat M. Desai, *Indian Journal of Agricultural Economics*, 49, 3, July-September 1994.

Table 2
Some Findings on Total Factor Productivity and its Determinants in Indian Agriculture: 1966-67 to 1989-90

	Details	Mean	Standard Deviation	Annual Compound Growth Rate[1]
1.	Total factor productivity i.e. Tornquist-Theil Index with 1980-81 Base	91.90	10.855	1.699a
2.	Index of barter terms of trade with 1980-81 Base (BTOT)	112.08	8.031	-0.741a
3.	Cumulative government expenditure on agricultural research & education and crop production program with 5-year lag in 1980-81 Prices (Rs.Million) (GERD)	22609	15775	14.965a
4.	P_2O_5 to N Fertilizer consumption ratio (PNR)	0.328	0.040	0.843b
5.	% of Canal irrigated area to total irrigated area (CIS)	39.24	1.833	-0.634a
6.	% of Literate rural population to total rural population (RLR)	32.48	5.200	2.224a
7.	Density of no. of regulated market yards, fertilizer dealers and field-offices of rural financial institutions per 1000 ha of net sown area (MBID)	1.39	0.136	-0.001
8.	Density of length (km) of rural roads per 1000 ha of net sown area (RRD)	86.39	45.285	7.327a
9.	Gini ratio of owned land distribution (ONLE)	0.7080	0.0010	0.009c
10.	Gini ratio of operational land distribution (OPLE)	0.7085	0.0063	0.049b
11.	Annual average rainfall (mm) (ARF)	930	103	0.191

a Statistically significant at 1 per cent
b Statistically significant at 5 per cent
c Statistically significant at 15 per cent

[1] Estimated by fitting an equation $\ln Y = a + bt$

Table 3
Estimated Multi-Variate Model of Determinants of Total Factor Productivity in Indian Agriculture: 1966-67 to 1989-90

	Details	Regression Coefficients	't' Ratio	Relative Ranking[1]
1.	Barter terms of trade (BTOT)	-0.155	-1.370c	7
2.	Cumulated government expenditure on agricultural research & education and crop production program (GERD)	0.094	2.142b	1
3.	P_2O_5 to N Fertilizer ratio (PNR)	0.077	1.659c	8
4.	% of Canal irrigated land (CIS)	-0.182	-0.694f	9
5.	% of Rural literacy (RLR)	-0.142	-0.363	3
6.	Density of regulated market yards, fertilizer dealers and field-offices of RFIs (MBID)	0.122	1.521c	6
7.	Density of rural roads (RRD)	0.031	0.386	5
8.	Gini ratio of owned land distribution (ONLE)	-7.473	-1.031e	4
9.	Gini ratio of operational land distribution (OPLE)	4.950	3.902a	2
10.	Annual average rainfall (ARF)	0.048	1.236d	10
11.	Constant	4.206	1.315d	
	R bar square	0.979		
	'F' statistic	106.51a		
	D-W statistic	1.92		

a Significant at 1 per cent
b Significant at 5 per cent
c Significant at 10 per cent
d Significant at 15 per cent
e Significant at 20 per cent
f Significant at 50 per cent

[1] Derived from standardized regression coefficients estimated as regression coefficients (s.d. of Xi ÷ s.d. of Y) ignoring signs where s.d. is standard deviation, Xi is i^{th} explanatory variable and Y is dependent variable.

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