THE ECONOMICS OF AGRICULTURAL RESEARCH AND DEVELOPMENT *

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Only a few days after my joining the Agricultural Prices Commission, Government of India, I received an invitation from Dr. Daroga Singh to deliver the Dr. Rajendra Prasad Memorial Lecture on the occasion of 32nd Annual Conference of the Society. I was in a real predicament. I knew your professional Soceity was doing me a great honour by extending this invitation and at the same time my new assignment will leave very little time for me to do full justice to your invitation. In an attempt to do both the jobs, I have really learnt how important time constraint is and how much difficult it is to allocate the time resources according to its marginal value productivity in alternative uses compared to the ease with which the production economists turn out MVPs of the conventional resources. I feel priviledged to have this opportunity to pay homage to the memory of Dr. Rajendra Prasad who was the President of the Indian Society of Agricultural Statistics for 16 years from its inception. Dr. Rajendra Prasad was amongst the most illustrious sons of India, and throughout his long and colourful political career he was a great advocate of integrated rural development. His concern for the welfare of the common man is too well-known to be described in words. I, therefore, feel honoured to do my bit in commemorating his memory through a few thoughts that I would be sharing with you on this occasion.

Your Society was indeed gracious to leave the choice of the subject to me. But this made my task even more difficult. I thought your Society would perhaps like me to address to the problems of agricultural price determination. However, I felt that I had just started grappling with this problem and that it was too early for me to share my thoughts with you on this subject, not hovig tested my hypotheses on the ground.

*"Dr. Rajendra Prasad Memorial Lecture",— during the 32nd Annual Conference of the Society, 21-23 December, 1978 at Ludhiana.

Before making the final choice of the subject on which I am speaking to you today, I turned it over and over in my mind and this is how I came to priortise economics of agricultural research relative to the problems of agricultural price determination for this occasion.

A school of thought would lead you to believe that prices are at the most only fine tuners of the system, and even if we attach more importance to the positive role of the price structure in developing a positive interaction with technology, it can at best provide only marginal incentive to the farmers in the adoption of improved methods of production and practices. This it must do and perhaps more. But no pitching up of administered prices can fully compensate for the lags in technology which in turn is used as proxy for agricultural research althogh it will be more appropriate to say that research expenditure is a proxy for technology. This is evident from the fact that even after the price support for gram was pegged at a level higher than the level of price support for wheat, it has not induced much shift of acreage from the latter to the former crop.

Likewise, notwithstanding the fact that the market prices of rapeseed and mustard have ruled higher than that of wheat, it has hardly induced much of a shift in acreage from wheat to these oilseeds. This is because no technological breakthrough is yet in sight in gram, rapeseed and mustard whereas wheat technology is getting more or less stabilized. Also, there is much lower coefficient of variability attached to yields and incomes from wheat than is the case with gram and oilseeds. All these attributes of technology weaken the role of price policy as an instrument for bringing about rapid adjustments in the production patterns. There are many more examples of this kind which bring out very clearly that price policy cannot provide positive interaction with agricultural technology unless agricultural research is intensified to fill the lags in technology in all such agricultural enterprises which have not so far witnessed a really significant breakthrough. This can best be done by promoting such researches which are not only technologically but also economically sound.

Prior to the independence of the country, the investment in research was considered, by and large, a luxury. The cult of academic freedom had gone too far in traditional institutions in India; so much so that it had little relevance to the specific needs of the country. It was only with the establishment of the I. C. A. R. in 1929 that agricultural research started taking some direction. After independence with the introduction of successive Five Year Plans for economic development of the country, it was realised that economic growth could not be sustained, much less accelerated unless it was backed by significant increases in research expenditure which was proxy for

advances in technology. The establishment of a large number of institutes of technology, agricultural research institutions and agricultural universities is a testimony to this effect. In fact, the size of agricultural research investment has now reached a level at which accountability is inevitably demanded.

Agriculture economists can make a real contribution by exlor-ing this new field of economics of agricultural research and development in depth. It would not be an exaggeration to say that the effect of a productive agricultural research can create such a formidable agricultural research constituency which would persuade the politicians and the administrators to allocate more and more funds to strengthen agricultural research which would help science and technology based agriculture become the real strategy of agricultural development in India. It is against this background that I have preferred to share my thoughts with you on the subject of returns to investment in agricultural research.

Economic performance of the agricultural sector in most countries has been largely determined by organised research and extension activities in those countries. On a global basis, it is estimated that expenditure on agricultural research rose from $ 1·3 billion in 1959 to $ 3·8 billion in 1974 in constant 1971 U.S. dollars.

Research expenditure in India is relatively small but it has been increasing fast. It rose from Rupees one crore in the 1st Plan to Rupees 55 crores in the 4th Plan. A provision of Rs. 109 crores has been made in the 5th Plan. But when the expenditure is viewed as a proportion of total public outlay, it remained almost stationary. It was 0·30% in the 2nd Plan, 0.35% in the 4th Plan and 0·28% in the 5th Plan. In contract, in north America and Europe it comes to 1·3%. In the current Plan (1978-1983) total expenditure on agricultural research is placed at Rs. 4·25 crores.

A growing realisation of the importance of research in agricultural growth has stimulated an objective assessment and estimation of the likely pay-offs to public investment in agricultural research. Recognising the significance of this problem, the Indian Council of Agricultural Research has set up an expert panel to investigate this problem.

The problem of measuring returns to investment in agricultural research are indeed beset with serious difficulties, both conceptual and practical. Even with advanced methodology available, researchers in the developing countries face a serious problem of lack of suitable information base for the pertinent variables.

Schultz calculated the value of inputs saved in agriculture, resulting from improved and more efficient production technique as a measure of return to investment in agricultural research. The concept of total factor productivity growth was used to measure the shifts in a production function by Hayami and Ruttan for Japan and the U.S. Agriculture respectively. Further, growth rate analysis and the factor share technique were used to study the change in factor share over time. Improvements in the technique used by them relate to shifting the weights used in the Index. Since the productivity measure is defined as per unit basis, at best, it gives the effects of only qualitative changes in inputs.

Sawada used a similar approach in his study of the sources of the growth of aggregate production in Japan. He estimated weights from outside for pooling the growth rates of different inputs. In this study, the assumption of constant returns to scale in the production function was made, which does not seem entirely realistic for Indian agriculture.

Evenson, Jha and Sawada have also used residual approach to measure returns to investment in agricultural research. When the residual approach is employed in the growth rate analysis, it is possible to include only selected major variables in the specified relationship. The residual will include the effects of excluded variables and of any measurement errors in the variables. Therefore, using the residual to measure the effect of research expenditure has some serious limitations. Moreover, since few of the variables contained in the model are independent of the effect of technology, it becomes even more difficult to attribute all of the residual effects to technology.

Again, Evenson and Jha measured marginal productivity of expenditure on agricultural research and extension through the production function analysis in which R. and D. (Research and Development) variables were included along with other factors of production. A major limitation of this type of analysis is that only partial returns to investment in research could be measured, holding other factors of production at a constant level. Since a change in the levels of other factors can also result from research expenditure, the coefficient of the research variable will be an under estimate of the returns.

Karam Singh tried to attack this problem by deleting the variable of research expenditure from the production function and

then used this production function to work out the shift in agricultural production at mean levels of inputs and attributed this to increase in research expenditure (with suitable lag time) over the pre-technology and post-technology periods. This type of analysis was done for the Punjab State to measure the change in returns over the two time periods. This approach gives only the shift but loses information on returns obtained during the different time periods.

Kahlon *et. al.* used the synthesis of this production function approach and the growth rate analysis and determined returns and internal rate of return to investment in agricultural research at all-India level. In the second part of this paper Saxena and Jha used the production function approach to estimate returns in different States. They also included the variable 'R' along with some of the input variables and the time variable in the functional relationship. This approach also measured partial marginal returns and the technique used suffered from some of limitations mentioned above.

To sum up, the factor productivity approach measured the effects of qualitative changes, the residue approach was affected by the specification of variables and form of the relationship and also included the effects of omitted variables. The production function analysis with or without the research variables measured the marginal returns and not the total return. Again, all these approaches required a long time series data on agricultural output and the relevant factors of production along with the R. and D. variables. The lack of this information has led to the use of a shorter time series with States as observations for the all-India analysis. But the estimates derived in this manner will not be appropriate unless output indices are converted into absolute value terms to account for interstate variation in the value of production in the base year. The major difficulty faced in this type of production function analysis is the estimation of elasticity coefficients from the time series analysis. The presence of trend in all these variables does not bring out the time shape of the relationship of output with these variables. Indeed, the change in output in relation to increases or decreases in input variables is not brought out from the use of time series data in which almost all variables are showing an increasing pattern.

If at all this type of analysis is to be attempted, it calls for the use of pooled time series data and the *cross* sectional data, the latter for estimating the elasticities and the former for estimating the presence of general trend in the coefficients of R. and D. variables.

Making use of the data from the farm management studies in some of the States (at two points of time representing the pre and

post technology periods) an attempt has been made in this direction. The results are presented in the ICAR Report on Cost-Benefit Analysis of Returns to Investment in Agricultural Research. This technique really improved the results. The problem of multi-collinearity and auto-correlation was reduced to some extent. However, even at a point of time, the presence of some multi-collinearity was there because of the complementary relationship in some related inputs. To overcome this problem, some variables were deleted from the production function analysis.

This type of improvement can be introduced for estimating returns in the States where such cross-sectional data are available. But the estimation of returns at all-India level still faces this serious problem of data limitation. This calls for further improvement in methodology in terms of pooling the state level data by developing some suitable weights and then estimating the production function using weighted least squares or some other suitable approaches.

With all these improvements in methodology, we still face the problem of correctly estimating returns from investment in agricultural research and development through the production functions approach because it includes the R. and D. variables along with the input variables which would measure marginal returns which are also partial. Certainly, when we measure increase in production/productivity as a result of one rupee increase in research expenditure, it is a marginal concept. This calls for further improvement in the model which does not use production function approach in the conventional sense, but uses functional relationship with R. and D. variables, assuming that the qualitative changes in inputs are entirely due to R. and D. variables and the quantitative changes are partly due to the general trend in input use. In this case the returns are estimated from the data on agricultural output and research and development expenditure.

Thus, keeping in view the limitations of the methodology used in the past studies, an attempt has been made to incorporate some improvements in estimating the returns to investment in agricultural research and development. These are :—

(*i*) The study accounts for the effects of partial trend in the factor use *i.e.* it eliminates the effects of general trend in input use which would be present because of the existing (old) technology even when there was no investment in agricultural research and development. This was done by incorporating the time variable (t) in linear or exponential form along with R. and D. variables in the functional analysis. The coefficient representing the partial growth

rate of agricultural output was used for adjusting the output for general trend in factor use.

(*ii*) The effects of the investments made prior to the study period were also accounted for. This was done by estimating the proportion of the present output which came from the R. and D. investments corresponding to the study period. The proportion (p) would be different for the two time periods, hence the agricultural output was further adjusted with this proportion.

(*iii*) The time lag was estimated by using the lag correlation technique. The maximum value of lag correlation (adjusted for degrees of freedom) along with the jump in R. and D. expenditures and the jump in agricultural output would reveal the time lag between investments and their returns. The time lag may vary from State to State or period to period. For the Indian situation, it worked out to be 5 years.

(*iv*) The output adjusted for past investments and partial trend was then attributed to R. and D. with a time lag of 5 years. Obviously, this analysis would help in estimating returns to R. and D. for each year in the two time periods. This would further help in showing the trend in these returns.

(*v*) This study also estimated the total returns, considering the effects of research investment at different time lags. This was done with the following assumption :—

> Suppose an investment R has an elasticity coefficient b with a time lag of 5 years. This investment will also have some effect after a time lag of 6 years, 7 years and so on. However, we can assume that the effect goes on decreasing. That is, R has effect to the extent of coefficient b after 5 years, coefficient λb after 6 years and $\lambda^2 b$ after seven years and so on, where $0 \leqslant \lambda < 1$. Thus, use of λ helped in getting total returns to an investment and this was incorporated in the functional analysis.

(*vi*) One of the significant improvements in this study was to separate out the effects of agricultural research from that of agricultural development. This was done by treating R. and D. as two independent variables with different elasticity coefficients. However, this model did not allow the use of different λ's. Adjusted output was then allocated to R. and D. in proportion to their elasticities.

SPECIFICATION OF THE VARIABLES :

In order to measure the returns to investment in agricultural research, it is necessary to identify the returns in terms of agricultural crop output (in value at constant prices) and the expenditure in terms of crop research expenditure (at constant prices). Our recent study considers the returns in terms of agricultural crop output (Y_t), the data on which are available from the National Accounts of Central Statistical Organisation, Government of India. The crop research expenditure (R_t) was compiled by Mohan, *et al.* The total agricultural research and development expenditure ($P_t + D_t$) can be compiled from the Combined Finance and Revenue Accounts of the Central and State Governments. The data on agricultural research expenditure may also be obtained from the Finance Reports by suitably combining the research items.

RESULTS :

The annual rate of growth of research expenditure was steady over the two periods, being 8·84 per cent in the first period and 8·93 per cent in the second. As regards the R. and D. expenditure, the growth rate per annum increased from 1·83 per cent in period I to 20·02 per cent in period II. The development expenditure (D) showed much variation over the entire study period with growth rate of 33·56 per cent per annum in Period I and 30·19 per cent per annum in Period II.

Return to one rupee investment (R+D) was much higher in Period II, being Rs. 4·64 as against Rs. 1·64 in Period I (Table 1). The internal rate of return worked out to be 10.40 per cent per annum in Period I, which was higher than the market rate of interest of 6 per cent per annum during this period. The internal rate of return was estimated at 35·90 per cent per annum during the second period and this again was much higher than the rate of interest of 10 per cent per annum prevalent during that period. The returns showed decreasing trend in the pre-green revolution period. However, these returns showed an increase in 1964-65 which was one of the best agricultural years. Thereafter, there was an abrupt increase in these returns which marked the impact of the green revolution.

RETURNS TO INVESTMENT IN AGRICULTURAL RESEARCH :

A return of Rs. 1.64 in the pre-green revolution period and Rs. 4.64 in the post-green revolution period does not highlight the effects of agricultural research and development. There are two drawbacks of this R+D analysis : firstly, the returns are calculated

TABLE 1

Returns to Investment in Agricultural Research and Development (R+D)

Year	*Output Y_t' due to (R+D) Expenditure (Rs. in lakh)*	R_E^*	*Internal Rate of Return*
1960-61	906.76	3.57	29.30
1961-62	874.82	2.35	18.70
1962-63	707.73	1.24	4.40
1963-64	836.82	1.17	3.10
1964-65	897.04	1.37	6.50
Average Period I	844.70	1.64	10.40
1967-68	3,865.35	4.87	37.30
1968-69	3,992.48	3.26	26.70
1969-70	4,190.84	5.49	40.60
1970-71	4,602.15	4.64	35.90
1971-72	6,605.35	5.19	39.00
1972-73	8,684.71	4.89	37.40
Average Period II	5,278.45	4.64	35.90

R_E^* – Returns to one rupee investment in Agricultural Research and Development.

from crop production alone and secondly that there are other more important social and economic benefits of agricultural development programmes. Most of these benefits are of qualitative nature and it is difficult to measure the returns in qualitative form from these benefits. Therefore, it becomes important to isolate the effects of agricultural research from that of agricultural development.

The elasticity of research expenditure worked out to be 0.0156 (non-significant) in Period I and 0.1078 (significant) in Period II. In case of the development expenditure, the elasticities were higher, being 0.2036 (significant) and 0.6075 (significant) in Periods I and II respectively. The adjusted output value $\left(Y_t'' \right)$ was allocated in proportion to the elasticities. The estimates were consistent because of the absence of auto-correlation.

Research expenditure did not show much impact during Period I. One rupee investment yielded a return of Rs. 1.91 with a

time lag of five years with internal rate of 14·00 per cent per annum (Table 2). Crop research was very rewarding in the second period,

TABLE 2

Comparative Study of Returns to Investment in Indian Agricultural Research, Using Different Approaches

Study	*Period*	*Returns to one rupee research expenditure*	*Time lag*	*Internal Rate of return*
Evenson-Jhan (8)	1953-54 to 1970-71	10.88	8	50.00
Kahlon *et al.* (15)	1960-61 to 1972-73	11.61	5	63.30
Present Study	1960-61 to 1964-65	1.91	5	14.00
Bal & Kahlon	1967-68 to 1972-73	14.91	5	71.70

giving a return of 14.91 rupees to one rupee investment The internal rate of return worked out to be 71·70 per cent per annum. Comparison of the research expenditure over the two periods showed that a 70 per cent increase in this expenditure resulted in seven-fold increase in returns. These returns are under-estimates because the future effects were not yet realised. The results so obtained are quite encouraging and suggest still higher allocation of funds to research in future.

The average returns to one rupee invested in the development of agriculture during Period I worked out to be Rs. 1.63 with an internal rate of return of 10.30 per cent per annum. The return figure for Period II was Rs. 4·14, the internal rate of return being 32·80 per cent per annum. Table 2 also gives a comparison of returns to investment from agricultural research and development as obtained from different studies.

Our recent estimate of Rs. 14.90 of returns to investment with 71.70 per cent internal rate of return is higher than the estimated returns of Rs. 10.88 obtained by Evenson-Jha. They estimated returns at 50 per cent internal rate of return. The difference in these two estimates results mostly from difference in the methodology involved. In fact, Evenson-Jha estimated marginal returns which came mostly from qualitative changes in the factors because of the concept of productivity per unit of input used in their analysis.

Also, general trend in the factor use and the effects of the previous investments were ignored in their analysis.

FURTHER IMPROVEMENTS ON THE MODEL :

Formal models for research resource/allocation are still in the formative stage. Further improvements in the results can be made by improving the quality of the data on research expenditure. Identification of the actual form of relationship (may be non-linear) between the variables should further improve the quality of the results. Use of long time-series data could also improve the efficiency of estimates of the elasticity coefficients.

The use of constant λ in the model was necessitated by short time-series in the concerned variables. The coefficient which represents the rate of change in the elasticity, need not be the same for research and development expenditure. If a longer series is constructed, it would improve the efficiency of the estimates and also permit the possibility of including more parameters by considering the variation in λ for some years.

The use of elasticity coefficient b assumes maximum effect at the point where the lagged correlation coefficient between agricultural production and the research expenditure was maximum. This can, however, violate a situation where some returns would be generated even before this point is reached. Further improvement on the model could be made by using some constant other than λ which would account for the small proportion of returns that might be generated before the point b was reached.

FUTURE OUTLOOK :

In India we have made a good beginning with ex-post analysis on measurement of return to investment in agricultural research. But there is very little work done to develop ex-ante project evaluation which would make an inpact on resource allocation decisions. The resistance to adopting this approach stems from the belief that output of research is completely stochastic in nature ; so it would not be worthwhile to estimate expected rate of return, particularly for individual projects. Indeed, it would be difficult to predict the outcome of most research with a high degree of precision, but research output is not all luck, which means systematic effort should be made to measure it. In fact, the procedure which is used for making ex-post assessment of research projects and programmes could also be used to evaluate 'ex-ante' the potential contribution of the proposed research projects to economic growth of the nation. The ICAR

research projects do raise questions on the likely benefits from the research proposal but without demanding quantitative measurements and their verification. Today, almost all the International Research Institutions measure the success of the project at least partly, in terms of the extent of the departure of realised B/C ratio, internal rate of return and the net present worth from the corresponding expected values estimated at ex-ante appraisal stage of the projects and the programmes.

It may well be that the time has come when we make a start in this direction. The target level of annual social benefit in any given year would be approximately equal to the product of potential annual social benefit and the proportion of output produced using the innovation, which in turn can be determined by the diffusion rate and the ceiling level of adoption of the innovation. I have no doubt in my mind that ex-ante analysis will improve the efficiency of research and also its credibility by enhancing the society's ability to use new knowledge.

Again, it is true that ex-post measures cannot automatically be taken to reflect ex-ante expectations. But on the basis of evidence produced in this paper, even the critics of agricultural research would agree that this activity has a very high pay-off. In fact, the returns on investment in agricultural research could be further raised by intensifying the research on research management and particularly on reorganisation and better coordination of the ICAR Central Research Institutes, their regional research stations located in the States and the agricultural universities and between various departments within the research institutes and the Agricultural Universities. A major reappraisal of the respective roles of the agricultural universities, ICAR Central Institutes and its regional research stations located in the states, is necessary to avoid duplication and increase the volume of productive research. The thrust of new research policy should come on developing complementarity between research programmes and projects of all these institutions. The ICAR is in a commanding position in executing research, development and extension in its own institutes and with its own staff but through its coordinated projects its can determine the direction of a substantial portion of the national agricultural research and development programmes. This should increase effective research capacity of the nation which is indeed a primary means to raising the agricultural productivity.

Prof. Evenson's research based on 39 State Experiment Stations in the USA indicates that the marginal return per research dollar was generally higher in stations with more scientists, more

graduate students, higher faculty salaries and higher levels of faculty training. He adds that "small scale research stations are characteristics of the countries with low levels of skill". Imperatives of the economics of scales demand that the unviable research stations be either closed down or expanded and better equipped to a scale which can attract the best scientists to these stations to be able to produce much better results. Perhaps, the best way to achieve these results would be to strengthen regional research which will often lead to more imaginative and viable research than every State setting up its own research stations on every commodity, knowing too well that the results of the research stations located in the neighbouring states are as much applicable to their agro-ecological conditions. This should reduce at least unneeded duplication.

Again, emphasis having shifted on proper identification of farmers' problems, which represented the critical limiting factor in the chain of events which led to making agriculture more progressive and productive, it was highly important to identify grass root problems in consultation with the local people who are more sensitive to their needs then is often realised. Japan benefitted by ensuring that local requirements of farmers were served by relevant research. I am inclined to agree with Prof. Bigs that "field observations, on-farm trials and analysis should be seen as a starting point for the establishment of research priorities". In addition to the extension service, the farm economists and agricultural statisticians can make a contribution here by conducting such agro-economic surveys which can concretise the problems and the issues posed by the local populations and provide a proper feed back to the biologists and other agricultural scientists who are engaged in developing appropriate technology for these areas and particularly for the weaker sections located in these areas. This approach should cut down the time lags involved in the development and the adoption of farm technologies which in turn step up the internal rate of return to investment in agricultural research. Following this approach, South Korea and Taiwan have reduced such lags to the minimum. There is no reason why we should not be able to do this in India.

INTER-DISCIPLINARY RESEARCH :

Global experience shows that inter-disciplinary research and training programmes have yielded high direct economic pay off in terms of new materials, more productive technologies and better institutional performance. The management of International Rice Research Institute has recently organised its programme management and budgeting around 11 inter-disciplinary research and training

programmes. India has just made a beginning in this direction. The ICAR is encouraging this development because it promises a much better pay off. It still, however, remains to be seen to what extent inter-disciplinary research exists even between different departments/ divisions of the same institution. The research workers from different disciplines do not seem to be very much enthused with this approach, since the system of rewards is not fully geared towards this end. Indeed it is high time that the performance of individual researcher in this country is evaluated more in terms of his or her contribution to promoting multi-disciplinary research than demonstrating that every other discipline is inferior to his own.

Time is running out. Let me conclude by saying that effective research capacity in developing countries is a primary means to raising agricultural productivity. The results reported here have shown extraordinarily high rates of return to investment in agricultural research. The R. and D. activity could, therefore, be further expanded to yield better social rates of return. Since the research production function still eludes an analytical specification, the Indian Society of Agricultural Statistics and Indian Society of Agricultural Economics can join hands to expland and dig deeper the area of this important new field of economics of agricultural research and development. And here lies a great promise. I have no doubt in mind that the profession will boldly face this challenge and further sharpen their tools of analysis that would help solve the problem of optimum research resource allocation and research priorities of the nation.