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THE ECONOMICS OF AGRICULTURAL RESEARCH IN BANGLADESH

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ABSTRACT

This paper is a preliminary study of three problems that Government policy-makers who are concerned with agricultural research at different levels have to face. The first problem is the allocation of funds between agricultural research and other investments that the government could make. The study shows that there has been a high pay-off to a very small investment in agricultural research in Bangladesh, and that some of this pay-off has reached all levels of rural society. The second problem facing officials is how to distribute funds between different institutes and between different commodities. Some relatively simple criteria are suggested which could be used in assisting this decision. Applying one of these criteria indicates that rice, fisheries, and livestock should be receiving more funds. The third problem is how to improve the efficiency of research institutes. It is suggested that scientists and administrators need more incentives to do practical research efficiently and also that there needs to be more contact between researdiers and farmers.

I. INTRODUCTION

This paper examines three problems regarding agricultural research which government policy-makers at different levels face. The first problem is the allocation of funds between agricultural research and other investments that the government could make. The second problem is that of allocating research funds efficiently between the different institutes and between different commodities. The third problem is how to increase the efficiency of these research institutes.

II. ALLOCATION OF FUNDS TO AGRICULTURAL RESEARCH

In order to allocate resources between agricultural research and other investment activities, planners would ideally like an *ex ante* cost benefit analysis of agricultural research and all of the possible alternatives. Then the planners would be able to rank these projects

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on the basis of some criteria like the internal rate of return of the investments. However, for a sector like agricultural research, which contains many programs each with a considerable degree of uncertainty about its outcome, a very detailed cost benefit analysis would probably cost more in terms of the time required for research than it is worth to the planners. Another somewhat simpler approach is to look at the recent history of agricultural research in this country and on the basis of the historical trend to try to make some judgements about the possible productivity of agricultural research over the next plan period. This can then be compared by planners with *ex post* analysis of other agricultural investment programs or *ex ante* analysis of programs when available.

In recent conversations at the Planning Commission the discussion of agricultural research seems to concentrate on the amount of money that is wasted and the needless duplication. There is admittedly waste and duplication in agricultural research in Bangladesh just as there is waste and duplication in most of the development projects in Bangladesh and elsewhere. However, there has never been a careful calculation of the contribution of new varieties to growth in output in this country and,perhaps more important, the discussions of the contributions that research has made have not compared these contributions to the small cost of agricultural research. This section of the paper will attempt to do these two things - first, to calculate the net social benefits which Bangladesh has gained from growing improved varieties of rice and wheat, and second, compare these benefits with the cost of these programs in Bangladesh.

There are two basic approaches to calculating the benefits from agricultural research. The first is to analyze the growth in aggregate output in order to find out how much of the growth in output is due to new technology. The second method is to take some easily identifiable new technology for which there is data and try to measure its impact on social welfare as measured by changes in consumers and producers surpluses.

When analyzing aggregate output growth, economists have usually used production function analysis. However, given the nature of the data required, the unreliability of agricultural statistics in Bangladesh, and the importance of such factors as revolutions, floods and droughts in recent years, simpler technique has been used. The Minhas-Vaidyanathan (MV) disaggregation technique has been used here. (See Appendix I for an explanation of technique). The results of this analysis are found in Table 1. The total growth in output of the seven major crops[1] which were used in this analysis was 13.9 per cent. The factor that contributed most to output growth was the increase in acreage. It increased by 7.3 per cent and accounted for over fifty per cent of the increase in output. The second most important factor was increased yields per acre. Yields grew by 6.4 per cent and added about 45 per cent of the increase in output. Shifts in the cropping pattern had a negative effect on output and the interaction between the yield and the cropping pattern effects was positive.

The increase of 1.9 million acres could be due to three factors : first, the cultivation of land that had been fallow, second, increase in double and triple cropping, and third, the shift of acreage from crops not covered by this analysis to the seven crops included. Over this period the net cropped area declined and fallow land increased which meant that the first factor did not cause the increased acreage. The total cropped area which is the single plus double plus triple cropped area, only grew about 300,000 acres during this period (Bangladesh Bureau of Statistics 1979). This accounts for only about 18 per cent of the increase in acreage reported. Therefore almost all of the increase in acreage of these crops was due to the shift from other crops to the seven crops used here.

The increase in yield per acre is the element of growth that is of most importance to this paper. The increase in yield per acre has been due to a combination of new technology and increased input use. The yield per acre of seven major field crops is shown in Table 2. All of the crops which increased in yield per acre except rape and mustard were crops in which new varieties had been introduced. The Aus rice crop is the only crop in which new varieties were introduced, but yields did not increase much. This is due to the fact that the local Aus varieties suffered a decline in yields and they balanced the yield increasing effect of the HYVs. Fertilizer use increased greatly during this period as farmers learned about the profits they could get from using it on local varieties and especially on the fertilizer-responsive HYVs.

Finally, there has been an increase in the percentage of area irrigated, which also helps account for some of the increase in yield per acre. The problem with the MV technique is that one cannot assign specific weights to the different factors that increase the yield per acre. Therefore, we must be satisfied that the MV technique indicates that the increase in yield per acre was an important factor in causing the growth in output during the period from 1965 to 1978.

The other method of calculating the benefits of new technology is to add up the net increase of consumers and producers surplus due to the new technology developed and introduced by Bangladeshi research institutions. (See Appendix II for explanation of this technique). This basically means adding up the net increase in value of agricultural output. This will enable us to identify more precisely the contribution made by agricultural research to growth. The most important of the new technologies that have been introduced or developed by the agricultural research program in Bangladesh are the new varieties of rice, wheat, and perhaps vegetables. The crops for which data on the acreage and yields of new varieties exists are rice and wheat. It is also these crops in which the HYVs have had their greatest impact.

The agricultural research system of Bangladesh is just starting to produce its own HYVs. Until a few years ago the main output of the research stations was the introduction of new varieties which were bred elsewhere and tested by the Bangladesh research program to see if they were suitable. Those varieties were approved by the government. Then they were multiplied and demonstrated by research people at the earlier stages and later by extension personnel. Without the research stations the Mexican wheats and IRRI rice varieties might still have found their way into the country and eventually become popular. However, they probably would have come in later and spread slower in the absence of the Bangladesh Rice Research Institute and the Agricultural Research Institute. In addition to IRRI and Mexican varieties some of the rice varieties developed locally have also become popular with farmers e.g. BR-3, BR-4.

To calculate the benefits to society two types of information are necessary. First, we need to know either the increase in yield/acre or the reduction in the cost of production which occurs when farmers shift their land from old varieties to new higher yielding varieties of a crop. The second type of data is the acreage which is planted with the new varieties. Table 3 contains the available information on yield per acre and cost of production from farm management data and aggregate official statistics.[2] Both the farm management data and the nationwide data have their problems. This table (Table 3) shows that new varieties definitely yielded more per acre than the old varieties. However, there is a lot of variance in the estimates of how much yields increased. The reduction in cost per maund gives a somewhat more realistic estimate of the effect of the introduction of new varieties. It takes into consideration the increased cost of producing new varieties which is due to increased fertilizer use and perhaps irrigation applications. Also, there is somewhat less variation in the change in the cost of production than in the change of yields. In order to estimate the net benefits from new varieties I have assumed that the cost of production of all varieties dropped by 25 per cent. This number agrees quite closely with the change in wheat cost of production and somewhat underestimates the change in the cost of producing rice.

The official acreage statistics of HYVs of wheat and rice are shown in Table 4. However, if we use official data to calculate the benefits to agricultural research, we will undoubtedly overestimate the acreage and production of new varieties and hence the social benefits from research. The Ministry of Agriculture sent out two HYV Aman Task Forces in 1974 and 1975 to check the reliability of official statistics on HYVs during the T. Aman season. Their conclusion in 1974 was "the actual acreage achieved in 1974 may be only 5 lakh instead of the 17 lakh reported." In 1975 they reported that "almost certainly, the overall inflation (of the HYV acreage) is by at least 100 per cent. The HYV Aman acreage could be less than 10 lakhs" (BMOA 1978).

Much of this overestimation was due to the inclusion of Pajam as an HYV. Rice scientists at the time were still not willing to accept it as an HYV, despite the fact that farmers and apparently the extension people who were collecting the data thought it was high yielding. Since this paper will try to distinguish between the varieties released and encouraged by the official research and extension system and other varieties (mainly Pajam), it is necessary to find the number of acres under IRRI and BRRI varieties. Therefore, the following adjustments were made to the official acreage and output series for HYV Aman. They are both reduced by 50 per cent until 1978 when Pajam was listed separately on the assumption made by the committee that the acreage inflation was of that size.

The social benefits which Bangladesh has received from the use of new varieties is shown in Table 5. The amount shown in this table is approximately equal to the increases in national income due to the new crop varieties listed in the table. The first four columns show the separate contributions of the various crops. The column labeled Total IRRI and Mexican is the calculation of benefits from research stations in Bangladesh. In 1976-77 this amounted to about 3 per cent of the total value of crop production. The other columns show the benefits derived from the introduction of Pajam rice by the Comilla Academy. However, since BRRI did nothing to encourge the spread of this variety, it cannot be counted as a benefit of government scientific research. These estimates of the social benefits from agricultural research assume that in the absence of the government research system these new varieties would not have been introduced and spread. This assumption is probably not correct because IR—8 was already being introduced through the Comilla Academy and the Mexican wheat varieties could have come in through neighbouring areas of India in which these varieties are grown.Thus, we should subtract the part of our benefits which would have occurred even in the absence of the research stations. In addition, the government researchers probably slowed the spread of Pajam by keeping it from being approved by the National Seed Board and by asking extension people not to promote it. Therefore I have tried to make some estimate of the size of these negative effects and have subtracted this estemate from the estimates in Table 5. With these subtractions I have developed the minimum estimates of the benefits of agricultural research which are found in Table 6. Appendix III gives a more detailed discussion of the necessity of reducing the original estimate of the benefits and the method which I used to do so.

The costs of agricultural research and the introduction of these new crop varieties consist of several items : the actual government expenditure on agricultural research, government expenditure on providing information, the costs to farmers of learning about the seed, subsidies on the new seed, and increased cost of the seed to farmers. There is little information on the price farmers actually pay for seed. However, there is data available on the size of the seed subsidy that the government paid. Thus, the three components of cost which are used in this paper are the government expenditure on crop research, the expenditure on extension, and the cost of the subsidy on seed. The data on the crop research is the actual expenditure given by the BARC's Inventory of *Agricultural Research Inventory in Bangladesh,* and the *Demands for Grants and Appropriation* from the Ministry of Finance. This data was converted into 1976/77 Takas. It is not clear how important the extension wing of the Ministry of Agriculture was in spreading the information about these new varieties. It has been found in other studies of diffusion that the main source of information about new technology is other farmers and relatives. However, we do not want to underestimate the cost of spreading new varieties because we are trying to make sure that the rates of return to these investments are not overestimated. Therefore, I have attempted to make a rough estimate of the cost of extension. I have used the actual budget expenditures for 1968/69 and 1975/76 on extension projects from the *Demands for Grants and Appropriations* both the Non-development and Development volumes.[3] Since much of this expenditure had nothing to do with the spread of wheat and rice varieties I have cut this expenditure in half to get a rough estimate of the cost of extension of information about these wheat and rice varieties. The size of the seed subsidy was reported for five years from 1973/74 to 1977/78 in the Report of the Committee on the Reduetion of Subsidies on Agricultural Inputs. I have taken the yearly average of the subsidy for those five years as the subsidy for every year from 1967/68 to present.

The costs and benefits for three five year periods are tabulated in Table 6. Research expenditure in the last period was 0·11% of the value of crop output. This places Bangladesh below almost every country in the world in its investment in agricultural research. This situation has improved in the last few years, but the amount invested is still very small. This table shows that despite the fact that Bangladesh did not have green revolution, the benefits from research relative to the amount of money spent on research were very high. In the 1970s the benefits to the nation were at least twice as big as investment and at most almost twenty times the current expenditure.

Internal rates of return to this investment in agricultural research were also calculated. It assumed that the costs of introducing and producing new varieties started in 1960/61 and ended in 1984/85. The spread of benefits was assumed to start in 1967/68 and continue until 1984/85. For the period from 1978/79 to 1984/85 the annual benefits were assumed to be the same as in 1977/78. The returns to the government's investments in research and extension under various assumptions are found in Table 7. Two cost series have been used. In the first we have included the cost of extension under the assumption that the formal extension system was important in spreading information about the new varieties. In the second column we have not included the cost of extension and so total cost equals expenditure on research plus the seed subsidy. Three benefit series were used.[4] The first assumes that in the absence of the formal government agricultural research system no IRRI rice or Mexican wheat varieties would have been used in Bangladesh. The second series assumes that the research system sped up the spread of these varieties somewhat and had a negative effect on the spread of pajam. The third series assumes that the research system was important only in spreading IRRI rice, not Mexipak wheat and that it slowed the spread of Pajam.

As Table 7 shows even with the most extreme assumptions about the cost of development and spread of new varieties and size of benefits, the rate of return to this investment was around 80 per cent. This compares very favourably with the returns on most public investments that have been made over this period and suggests that the government should invest more money in agricultural research in the future.

In addition to measuring the total benefits to society from the research, we must look at the distribution of those benefits among the different groups in Bangladesh. This analysis first looks at the evidence concerning which farmers are getting the benefits from the new varieties and then looks at the effect of these seeds on the landless. The only source of information for the whole country which breaks down the use of new varieties by farms of different sizes is the Report of the Pilot Agricultural Census, 1975. Table No.8 from this pilot census gives the percentage of farmers in each size category who use the HYV rice in the three main seasons. There are two conclusions to be drawn from this table: first, all farmers down to the lowest categories use HYV rice ; second, there is the very strong indication in this table of which farms benefited most. The farms in the 7.5+ group in each season except boro had the highest percentage of farms using the HYVs. The group below 0.5 acres group in size undoubtedly had the smallest percentage. Other information which was calculated from the census is in the last column. It indicates that for all HYVs a higher percentage of the total cropped land in small farms is under new varieties than from any other group. This means small farmers who do use new varieties put a much higher percentage of land under HYVs.

However, since large farms in this case have three times the land of the small farmer the income of the large farmer may have increased more than the small farmer.

Clay has estimated that the combined effect of the introduction of HYV rice was to increase annual labour requirements from 6.0 million man-years in 1960/61 to 7.36 million in 1975/76. This was offset somewhat by a decline of .12 million in jute which may have been at least partly caused by the increase in HYV rice varieties. Cost and returns studies conducted by the Agro-economic research unit and by U.S.A.I.D. show that the hired labour per acre used on HYV rice was greater than with local varieties. (Agro 1978a ; Agro 1978b; Church 1978a, 1978b, 1978c). Thus, some of the benefits have reached hired labourers. It is clear that in the absence of this increase in employment there would have been less demand for labour and the employment position of the landless labour would have been even worse than it is today.

III. ALLOCATION OF RESOURCES BETWEEN INSTITUTES AND COMMODITIES

Probably the simplest rule for allocating resources between different crops in an economically efficient manner has been discussed by Evenson and Boyce (1975). They say that : "If it were possible to say that the ease or difficulty of making a particular discovery was comparable for different research poblems, a simple rule could be stated. It would be that the ratio of the research expenditures for a commodity to the economic value of the commodity should be equal for all commodities."

This also implies that the percentage of the total amount of money spent on agricultural research which is spent on each crop should be equal to that crop's percentage share of the output of the agricultural sector.

Boyce and Evenson tested this rule with international data, which they have gathered. They found that the larger, more developed national agricultural research programs fit this rule very well, while the smaller less developed programs do not fit this rule. In addition, they found that over time the research programs in both the DC's and LDC's have been moving in the direction of this rule. Both these facts suggest to them that this rule is a fairly good approximation of economic efficiency. In the absence of any contrary empirical evidence, this would seem like a useful rule to start with.

It was originally hoped that the allocation of resources between different agricultural products could be calculated. However, this proved to be impossible because of the organization and accounting procedures of the multi-crop institutes. Instead, in this paper, the budget and the number of scientists at the various research institutes is compared with the value of all of the crops on which the institute conducts research.[5] Table 9 lists the main research institutes and the products which they are responsible for. It then gives the three year average of the value of these products. In Table 10 the value of the produce of each institute is compared with its budget. Several interesting results are apparent from this table. First, it would seem that rice is the most neglected area of crop research. The rice crop accounts for more than half of the value of output in the agricultural sector. Yet, it gets less than one quarter of the funds for research. In contrast BARI which deals with crops representing only about 11 per cent of the value of output received more than one third of all funds for research in 1976/77 and almost half of the scientists. The largest underinvestment appears to be in fisheries although the value of output per scientist implies that the budget figure may not be accurate. The other product sector which has had very little investment relative to its importance in the economy is livestock.

There are several problems with the Evenson-Boyce rule when one needs guidance in the planning context. They do not negate this rule, but it is useful to discuss these problems so that one can anticipate and plan for them. The assumptions that are necessary for this rule to lead to an efficient allocation of resources are the following : first, the time required and the probability of success in the research projects are equal ; second, the speed with which the new technique is adopted will be the same ; third, the equilibrium level of adoption will be equal in each crop ; fourth, relative prices of crops and inputs will remain the same ; and fifth, equal research effort brings equal results.

The length and probability of success of a research program which will produce improved technology will differ between commodities for several reasons. These differences are discussed in terms of crops but the differences are even greater when forestry, fisheries and livestock are included. First, in some commodities more basic knowledge is available than in others. This is largely due to historical circumstances. More work has been done on certain crops which were important in temperate countries which have more advanced scientific research programs and hence they came under study much earlier than many tropical plants. Second, the existence of international institutes like CIMMYT and IRRI for some crops and not for other crops like jute means that the availability and cost of knowledge is different for different crops. Third, some crops take longer to improve than others because of the ecological conditions under which they are grown. Crops that depend on rainfall or are grown in low-land, flooded conditions take longer to develop and to test than crops grown under irrigated conditions. A fourth reason for differences in the length of time and probability of success is the nature of the plant or animal which the scientist is dealing with i.e. cross pollinated crops may take longer to improve than self-pollinated. Fifth, different crops may be at different stages of development and the effort required to produce another new improved crop variety may be very great. This could be the case if most of genetic variability which is the basis of breeding new varieties has been used up. Jute is an example of a crop which until recently seemed to have used up most of the genetic variability and so the probability of producing a new improved variety was very low. Recently, however, there has been a breakthrough in basic knowledge about how to cross jute varieties which seems to have opened up a whole new range of genetic possibilities and hence increased the probability of breeding improved varieties of jute. Sixth, the efficiency of the institution and the quality of the scientists varies a great deal in Bangladesh which in turn affects their chances of success.

The assumption that the speed of adoption of different crops is equal also seems to have some problems. Some crops like tea and tree crops are going to spread at a slower rate than grain crops. Tea bushes are normally replaced only after they are 80 years old and so many plantation managers may be unwilling to replace the old varieties.

The final level of adoption of any new technique need not be the same in different crops. In Bangladesh a good example of the limits to the spread of new varieties is the situation in deep water rice. Currently farmers have varieties each of which fits into one level of flooding or time of harvest. Thus, one would have to breed varieties for each of these small areas. In contrast the conditions under which boro is grown are much more uniform, hence a few varieties can spread over a high percentage of the boro area.

Also, the economic impact of working on these various crops will vary with the difference in the shape of the demand curves and projections of future demand. The more elastic the demand curve, the greater will be the gains to producers of the crop. Thus, there may be some preference for research on export crops if it is the producers to whom we are trying to channel the benefits. If it is projected that there will be very little demand for a crop ten years from now as is the case for jute, it might not be wise to concentrate money and efforts on the crop.

The really important factors then in any cost benefit calculation are going to be the size of the increase in yield per acre or reduction of costs per acre and the number of acres which will be covered by the improved variety or technique. Unless there is a very large difference in the cost the difference in benefits, which are roughly the change in yield on cost, the times the acreage covered will overwhelm any differences in cost. An estimate of the increase in yield/acre or the cost reductions from different types of research might be determined by micro level agronomic-economic surveys or even from surveys which are only economic. The maximum acreage that would be covered by the new technique could possibly be estimated from the soil survey data as has been done in the past for new varieties of rice in rainfed areas of Bangladesh (Brammar 1974). Finally, the speed of diffusion could be estimated on the basis of the historical diffusion paths of new varieties.

Cost benefit analysis may also help in several decision making processes - assigning priority in research to the different crops ; choosing the appropriate disciplines to be given priorities ; and deciding between working on rainfed or irrigation crops. For example, this type of analysis suggests that the main plant research in Bangladesh should be on rainfed crops because they cover so much more area and thus the potential for spread of the innovation is so much greater. However, this is one area where one has to be careful because the cost of developing and testing a new technique on dry land may be substantially higher than developing and testing new techniques for irrigated land. An additional, more important caution about using cost benefit analysis at the project level is that it may not increase the precision of planning enough to justify the effort required for calculating rates of return or C-B ratios.

Which crops should be allocated the most money ? The most useful idea is probably to use some sort of check list. From this discussion of the economics of agricultural research the main questions that one would want to have answered in rough order of importance are :

1. What is the probability that new techniques will be discovered ?
2. How much acreage could new techniques cover and how fast ?
3. How much would new techniques increase yields or lower costs of the crop ?
4. What is the cost of improving these crops ?
5. What do we know about the effect of the innovation on the price of the crop ? Is the crop imported or exported ? Will internal and/or external demand for the crop be increasing ?
6. Has the institution which deals with this crop been successful in producing new technology in the past and does it have the capacity to improve this crop in the future ?

This check list for deciding research activities which is based on the goal of economic efficiency is not sufficient in a country like Bangladesh which has now taken as an explicit goal for the next five year plan to meet the basic needs of its people. These basic needs can only be met by policies designed to provide jobs for the rural landless labour force and by increasing the supply of food for that part of the population which is nutritionally deficient. Thus, the research policy of the country should also explicitly consider these goals and try to shape its policy so that new techniques will be labour absorbing and improve the diet of the poor.

By explicitly including increased employment as a goal of research the development of labour saving machinery would not be a high priority item unless it was needed to break a specific bottleneck and impove productivity. Also the choice of crop to be improved is important. The work of Jabbar and Faruque (1978) documents the difference in labour requirements of different crops. This should be taken into consideration. The investment in crops like jute or tobacco which employ 120 and 202 man-days compared to competing crops like Aus (66 to 80 man-days) and wheat (52 man-days) should be greater than a simpler efficiency rule implies.

In the nutritional field some very specific strategies have been suggested recently (Karim & Levinson 1979). It has been realized that the strategy of simply increasing output will not get rid of malnutrition. The example of India is frequently cited because currently there is a food grain surplus along with some of the worst malnutrition in the world. What is required is a strategy which increases the output of the crops which will be primarily eaten by the nutritionally deficient groups. From the poor consumer's viewpoint the most important factor in determining whether he will buy it or not is price. This suggests that researchers give more weight to grains like cheena, Kaon, barley, jowar, maize and sweet potatoes, which are all relatively cheap. This of course goes directly against the economic criteria which, if other things were equal, would suggest that researchers work on the higher valued crop. For the poor producer who is interested in improving his nutritional status the relative amount of calories or protein which he can produce per acre or per taka invested might be important. The most readily available evidence on this is the table from Karim and Levinson's paper which is reproduced below (Table 11). It indicates that the representative of coarse grains—sorghum—is the best crop in terms of calories per acre. However, these figures can only be taken as suggestive because the data on sorghum and sweet potatoes are from quite a small sample and also the yield of sorghum seems to be quite a bit higher than what will be produced if it is grown widely under farmers' conditions.

These last two paragraphs suggest we need to add several more questions to our checklist so that the problems of unemployment and nutrition are explicitly considered. In addition, any specific goals of the government can be added. Currently, the government's goal of reaching food grain self-sufficiency by 1985 cannot be ignored. Thus in addition to the questions on page 11 the following questions must be added :

7. Will improved technology in the crop under consideration increase the amount of total employment by either inducing the use of more labour on this crop or by shifting resources to more labour intensive crops ?

8. Is this a food crop which is generally eaten by nutritionally deficit groups ? Would the improvement of this crop allow poor groups to purchase more of the food which they need ?

9. Which food crops can most quickly be improved to double foodgrain production ?

IV. EFFICIENCY WITHIN THE AGRICULTURAL RESEARCH INSTITUTES

This section discusses two reasons for some of the inefficiency found in many of the agricultural research institutions in Bangladesh. The first is that most scientists and administrators in the public agricultural research system have little incentive either to produce results that are useful to farmers or to cut costs because there is no well organized group of farmers or consumers pressuring them for results. Partially as a result of this and partially for historical reasons the government structure within which most of them work is not structured to regard those who are productive. Secondly, there is little knowledge of the actual conditions under which farmers produce and so some of the new technology produced by scientists is inappropriate and the farmers will not accept it. The last part of this section gives the examples of two institutions in which scientists were motivated to produce practical results and knew what the farmers needed through direct contact with them . The results were two of the most successful research programs in Bangladesh.

The top managers of research institutes face problems of allocating resources efficiently. They must find the proper mix of manpower, land, equipment, buildings and working capital. They also must decide the most productive mix of disciplines and projects. Finally, there are the problems of which institutional structures are the most conducive to practical scientific research. Disciplines other than economics probably are more useful in dealing with most of these problems. However, if well defined projects can be specified within the research institute then cost benefit analysis similar to the eight point checklist described above could be used. Given the shortage of economists within the research system it seems unlikely that they will be available to do this type of evaluation in the near future. However, it would be useful if the scientists who propose the projects were required to go through this checklist. Then economists either within the institute or elsewhere could use this information to assess the economic impact of the project and this information could be passed back to the administrators who actually make the allocation decisions.

However, the inefficiency of the Bangladesh research system is not due so much to the fact that cost-benefit analysis, management sciences, or organizational sociology are not applied to the problems faced by the research managers. Rather there is little incentive for using any of these techniques or working for efficiency by any means. One of the reasons for the inefficiency of public research in Bangladesh is that at present most parts of this system have no active or influential constituency. There is no group of farmers or consumers who are really putting pressure on the agricultural research institutions to produce useful results. The majority of farmers have little interest in or direct influence on the goals of the research projects which scientists undertake, and they do not have the power to cut off the researchers' funds if practical results are not produced soon enough. Few scientists in a government research institution have to worry that they will lose their job if they do not produce results. Thus, there will not be the enthusiasm for practical results that is found at research stations in the U.S. or in the research programs of private companies, nor will there be the pressure for efficient utilization which is found in private companies attempting to minimize their costs of production.

In Bangladesh, research institutes do not have to satisfy the demands of a broad group of the population. Who do they have to satisfy in order to get more funds and to keep the old sources funding them ? Almost all of the money for agricultural research comes from the government, although there is a private research program working on tobacco. Indirectly much of the funding of public research is from the foreign donor community. Tea research is the only program funded by farmers and the trade although now it also is receiving a substantial amount of foreign support. Some research on the processing of certain agricultural products is funded by private companies. Since liberation, satisfying the government and the donors has for the most part meant convincing them that research is actually going on and that the results will soon be forthcoming. This is due to the fact that it was a new research system and that research is inherently hard to monitor and evaluate. The fact that there are few accurate statistics of the spread of new technology or accurate aggregate statistics on output growth means that the output of research institutions has to be evaluated on the basis of impressionistic evidence. In this situation the pressure for efficiency from the government or donors may be quite low.

In addition to the lack of presssure for efficiency in meeting the goals of the institutes the goals themselves may have little relationship to the actual needs of farmers or consumers. The goals of the agricultural research system as a whole have to reflect the goals of the central government which may reflect very imperfectly the needs of the people of Bangladesh. The goals of the specific research institutes are also influenced by the Ministry within which they operate and possibly the requirements of the donor or donors which are funding the research and providing the expertise.

Thus, for example, the Sugarcane Research Institute spends almost all of its efforts on improving sugarcane foruse in sugarmills despite the fact that 80 per cent of the sugarcane is used to make gur. This is because the institute comes under the Bangladesh Sugar and Food Industries Corporation which runs all of the sugarmills and is uninterested in gur.

At the level of projects within the Institutes, the Ministries have less importance, particularly in the autonomous organizations. The donors may still have some importance if they have resident experts on the station. However, for the most part, the goals of the researchers are defined by the researchers themselves based on their perception of what the farmers need and what the researcher needs in order to achieve his personal aims. If advancement comes by simply hanging on to his job long enough, or by breeding varieties that do well in the international trials or by publishing articles in Western scientific journals, it is unlikely that anything useful to the farmers will be produced. Since there are no farmers to get angry with him and threaten to cut his budget if he does not produce, there may be little incentive to produce.

Therefore, in the Bangladesh system instead of the farmers being involved in the process of deciding the goals of research programs, at best farmers can put pressure on an urban based central government, foreign donors, bureaucrats and scientists who ultimately decide on the goals of agricultural research. The decisions are usually taken in order to help the farmer, but some of these people and organizations have other priorities and goals which come in conflict with what is best for the farmer (Biggs, 1978).

The second problem is : The research institutes do not know what the farmers are doing and the conditions under which farmers have to operate. This again is at least in part the result of the lack of pressure for practical results. Farmers do not come to the researchers and tell them what they need and the researcher has no incentive to go out and find out what is going on. Because there is not enough information about the economics of fertilizer use in farmers' fields, the research system continues to recommend levels of fertilizer application which are never used by the farmers. The goal of the breeding program for deep water rice was to produce a variety that had the potential to produce about one ton paddy per acre but when they conducted surveys of yields in broadcast aman areas they found that many varieties already had the potential to produce that much or more. In the field of small scale agricultural engineering—particularly with regard to the modifications of the hand tubewell—farmers are far ahead of the researchers. To the extent that scientists are producing technology that will not be accepted by farmers or trying to solve problems that have already been solved by farmers, there is a considerable waste of scarce scientific manpower.

Several of the government research institutions have become aware of the lack of knowledge about farmers recently and are trying to correct it through various programs. At the top level BARC held some regional meetings on national agricultural priorities, which attempted to involve a broad spectrum of people in the planning process. BRRI has its cropping systems program which attempts to find out precisely what is going on in farmers' fields and then improve upon that. BARI has a number of programs including the work by the Field Trials Division and the agro-economic surveys of wheat and potato production which bring researchers in contact with farmers and provide basic information which can be used in planning research.

There are two research programs in Bangladesh which have managed to combine incentives for researchers and knowledge of perhaps farmers' needs into a successful research program. The research program of the Bangladesh Tobacco Company (BTC) is perhaps the best example of an efficient program to produce new agricultural technology[6]. Effective demand for results and close contact with farmers are probably the most important reasons for the success, size and structure of the BTC research program. BTC controls a substantial portion of the cigarette market in Bangladesh. Thus, it is in a position to capture most of the gains in profits from any cut in the cost of the industry's main input, tobacco. One way it could do this was to replace imported tobacco (all cigarette tobacco was imported in 1972) with domestically grown cigarette tobacco. To do this they needed a research program. Therefore, soon after liberation, a small program to introduce cigarette tobacco was set up. They successfully selected an Indian air-cured variety and an American Flue-cured variety which now make up 90% of the Bangladesh crop. At present only 3% of the cigarette tobacco is imported.

In order to minimize costs BTC has not acquired land of its own for experimentation. Instead, it rents in some plots from farmers. It has no Ph. D. scientists on its staff, and only a small number of skilled scientists with M.Sc. training. There are no foreign experts on the staff,, although BTC does have access to the knowledge and plant material of its parent company, British American Tobacco Co. It is only in the last year or so that they have had a laboratory building.

The efficiency of the BTC researchers is encouraged by three factors. First, there are economic incentives to produce results which are used by farmers. As a private firm it can reward the productive researchers monetarily and since it buys most of the tobacco there is a built-in system for evaluating farmers' acceptance of the new technology. Second, the selection and other research work is conducted in the agro-climatic areas in which the results will be adopted. The researchers live and work in these areas. Third, the researchers are in very close contact with the farmers. The research work all takes place in fields and is closely observed by the researchers. Thus, the researcher is in direct daily contact with the farmers. Finally, the economics of producing these varieties is monitored. Cost and return data are collected every year from farmers. The company can find out which operations have high costs and do research to reduce these costs. Thus the high cost of flue-curing led them to work on producing high quality, air-cured varieties and also to experiment with replacing wood by natural gas in the flue-curing process.

The Comilla Academy was perhaps the most successful program which attempted to build up a system which expressed the demands of the people for government services[7]. Through the Comilla model which had the Comilla staff working in the field doing social research and the leaders of cooperatives coming to the Academy for training, the needs of the farmers in the cooperatives were expressed. The Acamedy tried to provide the improved inputs when they were needed. Also, because of their basic faith in the farmers, they let them try various rice varieties after initial trials on a nearby cooperative farm. The motivation of the staff was not monetary like BTC but ideological which was also very effective.

The case of Pajam rice is revealing in that it indicates that the Academy was more aware of the practical needs of the farmers or more confident that farmers could determine their own needs than the regular research and extension people. A number of rice varieties were brought to Comilla by Japanese volunteers and through the IRRI representative in the 1960s. Several of these—IR-8, Taichung and Mashuri—became very popular. Mashuri, called Pajam in Bangladesh, was brought in by a Japanese volunteer. After testing it for a few years at the seed multiplication farm run by a cooperative near Comilla, the Academy staff distributed small portions of the seed to farmers who came to Comilla for training to try on their own fields in 1968. Farmers liked the variety and multiplied it themselves. It now is the most widely used improved variety of rice in Bangladesh. Several other varieties were also spread like this although none as widely as Pajam. When agricultural scientists outside Comilla tested Pajam on their stations, they found that it was susceptible to disease and was not very high yielding compared to IRRI varieties under conditions of good water control and high fertility. Therefore, they have actively discouraged its spread and the extension system has also played no role in spreading this variety. Despite this, the farmers know what was best under thier conditions. Pajam is currently the most widely used improved rice variety, and it continues to spread in the western part of the country.

In the absence of real political power in the hands of the farmers and an awareness on their part that agricultural research can provide very useful services to them, the current institutions that are trying to translate farmers' needs into a program of research may always have a tendency to move off the target. However, these examples of BTC and Comilla suggest that more contact with the farmers and actually listening to what they say or watching what they do is very important to having a successful research problem. Another thing that is suggested by these examples is the importance of actually monitoring the results of research in farmers' fields. BTC has done it through their collection of costs and returns data but even more important, they buy almost all of the crop. Therefore, they know excactly how successful their program has been. Information of this sort on the output of government agricultural research institutes could be very useful in putting pressure on institutes to produce useful results. At present very little such evidence is available. Finally, there have to be monetary or ideological incentives to the staff of these institutions to produce practical results which benefit the farmers and consumers of Bangladesh.

V. CONCLUSION AND RECOMMENDATIONS

This paper examines three problems regarding agricultural research which Bangladeshi policy makers at different levels face. The first problem is the allocation of funds between agricultural research and other investments that the government could make. The second problem is that of allocating research funds efficiently between the different research institutes and between different crops in the multiple crop institutes. The third problem is how to increase the efficiency of these research institutes.

A. Allocation of Resources Between Research and other Investments.

1. Growth in agricultural output was very slow between the mid-1960s and late 1970s.
2. The increase in yield per acre of the major crops was the cause of almost half of the growth in agricultural output.
3. A substantial part of this increase in yield per acre was due to the introduction of new crop varieties.
4. The investment in agricultural research has been very small—about 0.11 per cent of the value of agricultural output during the 1970s.
5. Although the increase in output due to technology developed by the agricultural research system was small compared to the size of agricultural output of the economy as a whole, it was large compared to the size of the government's investment in agricultural research. In recent years the benefits have been at least five times the current investment in agricultural research.
6. The internal rate of return to government investments in agricultural research, seed subsidies and extension work to help popularize the HYV's has been at least 30 per cent, which suggests that the government should invest more resources in agricultural research in the future.

B. Allocation of Resources to Different Institutes

1. On the basis of its importance in the economy of Bangladesh the crop institute in which there seems to be the greatest underallocation of resources is the Rice Research Institute.

2. It also seems clear that fisheries and livestock are neglected commodities in terms of the size of their research budget and the number of scientists working on them.

3. A more extensive economic analysis of the allocation of research resources should be undertaken both to verify the above conclusions and to further develop the methodology for allocating resources in the future. A checklist has been suggested as a way to start this analysis.

4. Any criteria for setting of priorities should include not only economic efficiency considerations but also employment and nutritional goals.

C. Allocation of Resources within Agricultural Research Institutes

1. Productivity of the institutes could be improved considerably if there were more pressure on the scientists and administrators for practical results. More monitoring of the actual output of research might be one way of applying such pressure.

2. Information about what the farmers actually need seems to be absent in all but the most successful programs of agricultural research. Information gathering institutions need to be improved.

3. More detailed study of some of the efficient research stations in the country even though they may be in the private sector may lead to some ideas about the more efficient combinations of material and manpower resources.

Footnotes

1. Rice, wheat, jute, sugarcane, masur, rape and mustard, and potato, which made up 90 per cent of the sown area in 1975-77.

2. The farm management studies are based on small samples in selected districts, and so, may not be very representative of the whole country. The aggregate data on the other hand is not much more than an eye estimate by village level extension agents, which have then been modified by their superiors to try to make them more acceptable to the government if not more accurate. They are supposed to be based on

crop cutting experiments but at present very few crop cutting are actually done. Thus, these are also not very accurate.

3. The expenditure 1968/69 included detailed account No. 40 categories A. Directorate of agriculture (E&M), B. Superintendence, C. Subordinate and Expert Staff, D. Experimental Farms, E. Agricultural Demonstration and Propaganda. In the Development Account No. 63-B the schemes included Rural Demonstration Farms : Expansion of the Agricultural Information Service ; Scheme to Popularize Fertilizer ; and the Extension Training Institute. The Capital expenditure account No. 71 categories included expenditure on the Soil Testing Institute ; The Agricultural Extension Institute ; the Plant Protection Services Scheme ; Seed Stores ; and the Agricultural Infrormation service. For 1975/76 expenditure was from basically the same categories except that the number of schemes under development Account 64 (the same as the earlier 63-B) seems to have been reduced by incorporating them into a general category of Extension and management.

4. See appendix III for discussion of different assumptions about benefit series.

5. This excludes the Institute for Nuclear Agriculture and the Universities because they work on many commodities.

6. Information on BTC was collected in interviews with BTC executives.

7. Information gathered in discussions with A.H. Khan and Dr. Akanda in 1979.

TABLE 1 RELATIVE CONTRIBUTIONS OF DIFFERENT ELEMENTS TO THE GROWTH OF CROP-OUTPUT 1964-67 to 1975-78[a]

Element of growth	Percentage increase in output over the period	Per cent contribution to total change
Acreage	17.3	52.1
Yield	6.4	45.7
Cropping Pattern	—2.7	—19.3
Interaction	3.0	21.4
All elements	13.9	100.0

a. The technique used to calculate the figures in this Table is explained in Appendix 1.

TABLE 2 YIELD/ACRE (Mds)

	64/65-66/67	75/76-77/78	% Change
Rice			
Aus	10.53	10.63	0.95
Aman	12.4	13.62	9. 8
Boro	15.4	21.8	41. 6
Wheat	7.63	17.71	132. 1
Jute	14.92	14.63	-1.95
Sugarcane	515.02	488.04a	-5.24
Masur	7.63	7.08	-7.21
Rape & Mustard	5.45	6.27a	15.05
Potato	86.38	102.73a	18.93

a. Only figures for 1975-76 and 1976-77 available.

Source : BBS 1976 ; GOB 1973 ; BBS 1979.

TABLE 3 YIELD PER ACRE & COST PER MAUND OF RICE & WHEAT VARIETIES

	Yield/Acre				Cost of Production (Tk./Maund)		
Boro	Mymen[a]	Mymen[b]	Comilla[b]	all Districts[c]	Mymen[a]	Mymen[b]	Comilla[b]
Irri	46.7	53	52	27.61	36	42	37
Local	37.1	20	24	15.69	42	60	42
% Change	26	165	116	75.0	-14.3	-30	-11.9
Aus	Mymen[b]	Faridpur[b]	Comilla[b]	All Districts[c]	Mymen[b]	Faridpur[b]	Comilla[b]
HYV	44	48	44	25.61	52.7	36.3	48.5
Local	14	16	18	8.44	110.6	73.8	79
% Change	214	200	144	203.4	-52.3	-50.8	-39.07
T. Aman	Dinajpur[b]	Comilla[b]		All Districts[c]	Dinajpur[b]	Comilla[b]	
HYV	40	47		19.88	31.0	37.1	
Local	19	20		12.59	47.4	55.3	
% Change	110	135		57.9	-34.6	-32.9	-
Wheat	Pabna[a]		Rangpur[d]	All Districts[c]		Pabna[a]	Rangpur[d]
HYV	Unfert. 19.1	Fert. 22.3	20.76	21.78	Unfert. 45	Fert. 43	37
Local	11.6	15.6	8.13	7.84	64	57	51.0
% Change	65	43	15.5	178	-29.7	-24.6	-26.3

Sources : a. GOB 1978a ; GOB 1978b

b. Church et al. 1978a ; Church et al. 1978b ; Church et al. 1978c.

c. BBS 1979. d. Rahman 1978.

TABLE 4 ACREAGE UNDER IMPROVED VARIETIES

(1, 000s of Acres)

YEAR	BORO IRRI BRRI Area	%	BORO PAJAM Area	%	AUS IRRI BRRI Area	%	T.AMAN IRRI BRRI Area	%	T.AMAN PAJAM Area	%	ALL RICE IRRI BRRI Area	%	ALL RICE PAJAM Area	%	WHEAT HYV Area	%
1967/68	156	10									156	6			3	1.6
68/69	160	17			17	.2					376	1.6			21	7.2
69/70	580	26.5			48	.5	29	0.2.			652	2.6			23	7.7
70/71	857	35.3			80	1.0	200	1.4			1137	4.7			33	10.6
71/72	795	36.4			121	1.6	626	4.6			1542	6.7			37	11.8
72/73	1088	44.7			164	2.2	1377	8.8			2630	11.1			53	17.8
73/74	1454	56.0			329	4.3	2043	14.4			3827	15.7			73	23.6
74/75	1629	56.7			699	8.9	1239	9.2			3567	14.7			82	26.4
75/76	1587	55.9			872	10.3	1376	9.6			3835	15.0			218	58.8
76/77	1215	57.5	123	6	901	11.3	1046	7.2			3163	13.0			288	72.9
77/78	1455	53.8	131	5	981	12.6	567	4.1	666	4.2	3003	12.2	797	3.2	389	83.3

Sources : IRRI Rice Varieties 1967/68-68/69 : BBS 1976
Rice 1969/70-77/78 : BBS 1979.
Wheat : Clay 1978.

TABLE 5 SIZE OF BENEFITS BY CROP

(1,000's of 1977 Takas)

YEAR	Boro	Aus	T. Aman (Adjusted)	Wheat	Total IRRI+Mexican	Pajam (Boro)	Pajam (Aman)	Total	Grand Total
67/68	50441			490	50931				50931
69	131532	2134		3555	137221				137221
70	237749	5469	9712	4240	257170	9291	26255	35474	292644
71	375035	10484	28968	6303	420790	21297	45171	66468	487258
72	307310	13866	93832	7219	422227	25397	65199	90596	512823
73	461356	18207	176377	8889	664789	40440	85707	1261147	290936
74	641997	43990	346981	14525	1047493	54357	128476	182833	1230326
75	655008	94862	195916	17274	963060	65904	138613	204517	1167577
76	659802	124763	240205	79626	1104396	78781	189988	268769	1373165
77	486629	128380	356184	122116	1093309	65119	213545	278664	1371973
78	617702	147156	198657	193224	1156739	73389	238074	311463	1468202

TABLE 6 AVERAGE ANNUAL BENEFITS AND COSTS OF AGRICULTURAL RESEARCH (LACS OF 1976/77 Tks.)

	Costs			Benefits	
	Res. Exp.	Seed Subsidies	Extension :	Max.	Min.
1960/61-64/65	84.8				
1965/66-69/70	109.3	100a	350	1484.0a	435.7a
1972/73-76/77	397.0	100	500	9746.1	2187.8

Sources : Research expenditure 1972/73-76/77 : BARC 1978
Research Expenditure 1960/61-1969/70 : BMOF
Seed Subsidies : GOB 1979
Maximum Benefits : Table 5.
Minimum Benefits : Appendix.
a. Average of the three years 1967/68-1969/70.

TABLE 7 RETURN TO INVESTMENT IN AGRICULTURAL RESEARCH

	Cost Assumptions	
Benefit Assumptions	Extension included as a cost	Extension not included
All IRRI and Mexican Wheat due to Research	50	60
Some IRRI & Wheat, due to Research, Pajam slowed.	30	35-40
Some IRRI, no Wheat due to Research, Pajam slowed.		30-35

Rates of return were calculated as the r which will make the following equation equal to zero :

$$\sum_t (B_t - C_t)(1+r)^{-t} = 0$$

where :

B_t = benefits from new varieties at time t

C_t = government expenditure on agricultural research, seed subsidies and in column 1 extension.

TABLE 8 PER CENT OF FARMERS IN EACH SIZE CATEGORY USING HYVs BY SEASON

Farm Size (acres)	T. Aman (1)	Aus (2)	Boro (3)	Per cent of Total Cropped Acreage in Each Group Under all HYVs (4)
0.0-2.5	5.1	5.44	14.39	6.60
0.0-0.5	3.63	1.14	13.19	
0.5-1.0	5.08	5.00	13.89	
1.0-2.5	5.31	6.14	14.71	
2.5-7.5	7.9	5.25	9.06	3.77
7.5+	7.39	10.05	14.05	3.30

Source : BBS 1978

4—

TABLE 9 RESEARCH INSTITUTIONS AND VALUE OF COMMODITIES

Institutions	Name of crops	Annual production 1975-78 (000 tons)	Value of production (Million Tks.)
Rice R.I. (BRRI)	Rice Aus	3,1115	6,752
	Rice Aman	7,124	19,908
	Rice Boro	2,056	5,298
	Total	12,295	31,958
Agricultural R.I. (BARI)	Wheat	271	564
	Barley	15	31
	Jowar	1	2
	Maize	2	4
	Other rabi crops	14	28
	Other bhadoi crops	13	27
	Cheena	16	33
	Vegetables	2,308	1,599
	Potato	821	747
	Sweet Potato	764	354
	Cotton	4	6
	Tobacco	52	342
	*Pulses	224	409
	Edible Oil seeds	66	246
	*Spices	246	887
	Fruits	1,402	1,932
	Total		6,131
Jute R.I. (BJRI)	Jute	4,701	
	Mesta	68	
	Total	4,769	2,313
Tea R.I. (BTRI)	Tea	52	741
Sugar R.I. (BSRI)	Sugarcane	6,319	1,719
Fisheries R.I. (FRI)	Fish		7,889
Forestry R.I. (FRI)	Forest Products		1,893
Veterinary R.I. & Livestock R.I. (VRI+LRI)	Livestock & Poultry		4,494
Grand Total			57,138

Source : Average annual production from BBS 1978.
* Two-year average—1975/76 and 1976/77.

TABLE 10 RESEARCH INSTITUTIONS' MANPOWER, BUDGETS AND VALUE OF THEIR CROPS

Institutions	Value of Output (Million Tks.)	% of total output value	Scientists Ph. D. & M. Sc. s 1976	Budget 1976/77 (Million Tks.)	% of total budget	Value/ budget	Value/ Scientist
BRRI	31,958	56.73	30	16.9	23.21	1891.01	1065
BARI	6,131	10.88	113	24.1	33.10	254.3	54
BJRI	2,313	4.12	38	6.9	9.48	335.2	61
BTRI	741	1.32	14	4.3	5.91	172.3	53
BSRI	1,719	3.05	18	8.5	11.86	202.2	96
FRI (Fish)	7,089	12.58	15	.6	.82	11815.0	473
FRI (Forest)	1,893	3.36		8.0	10.99	236.6	
LRI VRI	4,494	7.98	16	3.5	4.81	1284	281
TOTAL	56,338	100	244	72.8	100	16190	2083

SOURCES : Value of output - Table 7.

Budget and Scientists - All Institutions except Livestock Research Institute (LRI) from Agricultural Research Inventory, Bangladesh, Part I ; Finance, Manpower, Physical Facilities, BARC, July 1978; LRI from Kazi M. Badrudozza, "Organization and Accomplishments of Agricultural Research in Bangladesh", Second FAC/SIBA Seminar on Field Food Crops in Africa and the Near East, Lahore, Pakistan, 18 September to 5 October, 1977.

TABLE II COMPARATIVE PER ACRE PRODUCTION DATA FOR RICE, WHEAT, SORGHUM AND SWEET POTATOES IN BANGLADESH

Crop	Yield (mds)	Calories (000)	Production Cost (Tks)	Calories Per Tk.
Rice (Irrigated Boro) a b	35	452	1741	260
Rice (Rainfed local) a c	25	323	1552	208
Wheat (Irrigated **Sonalika**) d e	27	348	1439	242
Wheat (Rainfed local) d f	12	155	765	203
Sorghum[g]	35	455	829	549
Sweet Potatoes[g]	108	483	1817	266

a. Agro-Economic Research, Bangladesh, Ministry of Agriculture and Forests, *Costs and Returns of Boro Paddy,* 1978.

b, Babuganj Thana, Barisal.

c. Itna Thana, Mymensingh.

d. Agro-Economic Research, Bangladesh Ministry of Agriculture and Forests, *Costs and Returns of Wheat,* 1978.

e. Meherpur Thana, Kushtia.

f. Sujanagar Thana, Pabna.

g. Mennonite Central Committee studies in Noakhali and Comilla districts.

Source : Karim and Levinson 1979.

APPENDIX I

By subtracting the crop output in the first period from the value of output in the second we get the increase in output over this time period. This increase $(P_t - P_o)$ can then be broken down into the components of the increase by algebraic manipulation.

$$
\begin{aligned}
P_t - P_o &= A_t \sum_i W_i C_{it} Y_{it} - A_o \sum_i W_i C_{io} Y_{io} \\
&= [(A_t - A_o) \sum_i W_i C_{io} Y_{io}] \\
&+ [A_t \sum_i W_i C_{io} (Y_{it} - Y_{io})] \\
&+ [A_t \sum_i W_i Y_{io} (C_{it} - C_{io})] \\
&+ [A_t \sum_i W_i (Y_{it} - Y_{io}) (C_{it} - C_{io})]
\end{aligned}
$$

Where, P_o = crop output in year 0

P_t = crop output in year *t*

A_o = Gross crop area in year 0

A_t = Gross crop area in year *t*

C_i = the proportion of the total area under crop *i*,

Y_i = the yield rates of crop *i*

"W_i refers to the constant price weights (1976/77) assigned to each crop, and time period 0 refers to the average for 1964/65 to 1966/67 and *t* to the average for 1976/77 to 1977/78" (Hossain).

The first term on the right hand side of this equation is the increase in value of output which would have occurred if acreage had increased but all other things had remained constant. The second term on the right hand side gives us the effect of the increase in yield although it is weighted by the acreage in the final period rather than in the first period and thus somewhat overestimates the pure yield effects. Term three is primarily the increase due to the change in the cropping pattern, and like term two may be somewhat biased by the use of acreage in the final period. The final term is the interaction effect showing the contribution of the interaction between the change in yields and the change in cropping patterns.

APPENDIX II*

In this paper the concept of producers' and consumers' surplus has been used to measure the benefits from agricultural research. The improved technology embodied in the new rice and wheat varieties lowers the cost of producing a unit of grain and thus shifts the supply curve of grain downward as shown in Figure A.I. (from SO to S_rO). This

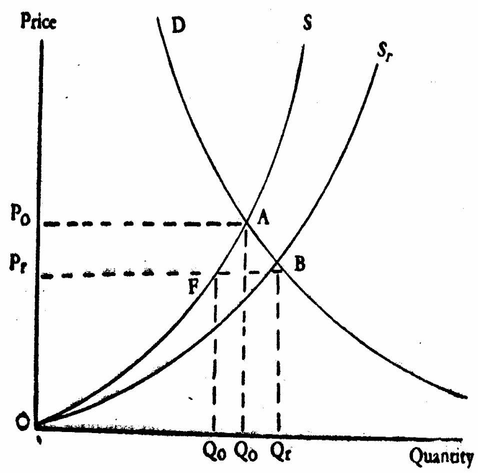

FIGURE A. 1

shift increases the size of the consumers' surplus by the area AP_oP_rB. It also changes the size of the producers' surplus by the area BFO minus the aera AP_oP_rF. The total change in the economic surplus will be the area AOB.

*The methodology in this appendix is taken from the article by Evenson and Flores.

To measure the areas of these surpluses Akino and Hayami have developed the following approximations :

$$\text{area AFB} = \frac{pq[k(1+b)]^2}{2(b+n)}$$

$$\text{area BFO} \simeq kpq$$

$$\text{area } AP_oP_rF \simeq \frac{kpq(1-b)}{b+n}\left\{\frac{1-k(1+b)}{2(b+n)} - \frac{k(1+b)}{2}\right\}$$

To calculate the total change in economic surplus area AOB it is necessary to add the areas AFB and BFO.

$$\text{Area AFB+BFO} \simeq kpq + \frac{pq[k(1+b)]^2}{2(b+n)}$$

where

p is the price of the crop
q is the output of the crop
k is the shift of the supply curve
b is the price elasticity of supply
(-n) is the price elasticity of demand

The 1976/77 prices for each of the rice crops and the wheat crop were used in this calculation. The quantity produced each year was the q in the above equations. The shift in the supply curve (k) was estimated by multiplying the percentage decrease in the cost of production due to switch to the new varieties which we estimated to be approximately 25 per cent times the percentage of acreage under new varieties in each year. Thus for a year when 10 per cent of the rice area was under new varieties k would equal ·025. The price elasticity of supply for rice was taken to be ·18 as estimated by Cummings (1974), and the elasticity of demand used was −.3.

APPENDIX III

The estimates of social benefits in Table 5 assume that in the absence of the government research program new varieties would not have been introduced and spread. This may be a valid assumption in cases where a variety was the result of a breeding program. However, when the new variety was simply the introduction of a variety from another part of the world, it is not clear how necessary a large research program was. This is particularly true in the case of IRRI rice and the Mexican wheat. These varieties were widely publicized so that the government did not need researchers to tell them about their value. They were adaptable to agro-climatic conditions in large areas of Bangladesh. Thus, the main requirement was the seed of the new variety and a few acres of land on which to test it. The Academy for Rural Development at Comilla provided land for testing and seeds for Taichung, Pajam, and IR-8 until the Rice Research Institute came into operation in the late 1960s. Thus, in the absence of a government research program IR-8, IR-5 and IR-20 could have been distributed by the Comilla Academy. The wheat varieties could have come in either through the government extension service or across the border from India. So a more realistic assumption than the complete absence of new varieties would be that the new varieties would have been introduced later and spread more slowly in the absence of the government research institutes. With these assumptions the benefits to research are no longer the entire surplus found in Table 5. Instead, they are the surpluses in Table 5 minus the surplus which would have occurred without a government research program.

Another factor that would reduce the size of the benefits is the negative effects on agricultural production which research stations might have. In the case of Bangladesh there is a particularly well documented example of this, but similar examples also exist in Pakistan and elsewhere. The rice variety Mashuri, which is known as Pajam in Bangladesh, was smuggled into the country by Japanese volunteers and popularized by the Comilla Academy in the late 1960's However, government plant breeders argued that in their tests it was lower yielding than the IRRI varieties and that it was less disease resistant. They were able to prevent it from being approved as an improved variety until the last few years. This meant that extension agents were supposed to discourage its use. More important, the government did nothing to increase the seed supply—Pajam was not multiplied on government farms and it was not imported from abroad. Despite this, Pajam is the most widely used improved rice variety and is still spreading quite rapidly in the western and northern parts of the country. With government publicity and seed multiplication, this spread would have taken place at a faster rate. In order to get the actual net benefits of the research program, we have to find out the difference between what the benefits would have been if Pajam had been an approved variety and the actual benefits from the spread of Pajam. This difference should then be subtracted from the total benefits which we attributed to agricultural research.

To correct the original calculation so that it reflects the spread of new varieties in the absence of regular research system and the negative effects of the research institutions on the spread of Pajam we have to guess at what the rates of spread would have been without research. We have recalculated benefits with two different sets of assumptions in order to get a lower bound estimate of benefits. First we assumed that agricultural research was responsible for only one-third of the spread of Irri rice and Mexican wheat (the rest of the spread would have happened anyway) and also that these institutions cut the spread at which Pajam spread by half (Column 2 Appendix Table 1). Second, we also calculated benefits assuming that the research stations were responsible for one third of the IRRI rice, none of the wheat, and cut Pajam by one half (Column 3 Appendix Table 1). Obviously, these assumptions are very arbitrary. However, they do serve the purpose of finding a lower bound to the benefit estimates.

Appendix Table 1 Estimated Benefits from Research under Different Assumptions

	Irri+Wheat	$\frac{1}{3}$(Irri+Wheat) $-\frac{1}{2}$ Pajam	$\frac{1}{3}$ Irri $-\frac{1}{2}$ Pajam
1967/68-1969/70	1484.0	435.7	408.2
1972/73-1976/77	9746.1	2187.8	1702.94

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