OPTIMAL RESEARCH, INDUCED INNOVATION, AND AGRICULTURAL DEVELOPMENT: AN APPLICATION TO BANGLADESH

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ABSTRACT

The literature of development economics is marked with an interesting rhythm. In the fifties it regarded agricultural growth as the main source of economic development. Attention gradually shifted, and industrialization was prescribed as the panacea for the developing economies. The trend reversed once more, and agricultural sector has risen into prominence in recent years. Another remarkable recent development is the revival of interest in the analysis of the source and effects of technical change. These topics of current interest constitute the basic theme of the present study which aims at integrating the question of agricultural growth with that of induced technical change, placing special emphasis on the distributional aspects of such change. It opens up with the appalling observation that there exists a huge gap in agricultural productivity among different countries which cannot be explained by variations in soil fertility alone. Proceeding further, the study finds that investments in agricultural research and extension programmes contributed significantly in raising the farm productivity of different countries. The essential features of agricultural development are analysed next as a means to increasing our power of interpreting the process. The resulting analytical framework is used to examine the nature of agricultural

transformation in Bangladesh. It is found that despite favourable influences of some forces, lack of proper and pragmatic public sector policies stood in the way of agricultural development of the country. This leads to the natural extension of the study to a vitally important but hitherto neglected area in which a formal model is developed to help the public sector find out the optimal allocation of its research and extension funds among various alternative farm activities. The model deals with a finite number of such activities and determines the efficient allocation in each crop subject to explicit physical and financial constraints. In addition, it also throws some light on the distributional effects of postulated technical change. The model is empirically implemented in the context of four major production activities in Bangladesh involving jute, rice, sugarcane, and tea. In order to achieve this, different parameters of the model are estimated through econometric and other techniques. The results of the analysis reveal certain interesting facts. Rice is found to dominate other crops by virtue of its massive share in total agricultural output of the country. However, the conditions of final demand and the costs of the programme turn out to be important variables in the allocation of funds to the remaining crops. Among them sugarcane dominates the rest, followed by jute and tea. It is also found that technical change in rice production will be detrimental to its producers. This finding is important in several respects, but most important, it suggests that the public sector should take deliberate steps to offset the loss accruing to the rice growers to induce them to adopt the new technology.

Studies related to the allocation of resources to agricultural research and extension programmes are very few. Given that the agricultural sector is highly important in the economies of most of the developing countries, and that its performance has been quite disappointing in all but a few of them; the agricultural development strategies of many countries need to be re-examined and reformulated. The present study can be of some help in attaining this objective. However, this is one of the first studies in this area and these issues cannot be resolved on the basis of a single investigation. Repeated studies encompasssing aspects of the problem that we were unable to incorporate will lead to the gradual accumulation of knowledge, permit a better understanding of the phenomenon, and help evolve a more effective way to deal with the entire issue.

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CHAPTER I

INTRODUCTION

I.1 Statement of the Problem

In the face of the rapid population growth experienced by most of the countries of the world coupled with a limited supply of natural resources, the main hope for increasing or at least maintaining the present level of consumption of goods and services hinges on raising the productivity of existing resources. Increments in factor productivity usually take place through technical change which can be either exogenous or endogenous in character. The analysis of sources of technical change is a recent phenomenon and received a great impetus along with the revival of interest in the theories of induced innovation.

In their pioneering study of agricultural development process Hayami and Ruttan (1971) have applied the theories of induced innovation to the study of technical change in the agricultural sector.1 Focusing on the experiences of Japan and the U.S.A., they observed that the major force behind agricultural growth in these countries emerged from the identification of the constraints on productivity created by the factors in inelastic supply and from the deliberate steps taken by the public sector in those countries to ease the constraints. Similar studies of the agricultural development process of certain other countries tend to substantiate the above findings, directly or indirectly.

On the other hand, technical change in agriculture is associated with several perceptible influences on the society. First, by encouraging the use of certain factors of production, it can alter the pattern of income distribution among them. Second, by increasing the supply and lowering the price of the crop undergoing technical change, it can create differential effects on the producers and consumers of the crop. Finally, by altering the mixture of available products, it can change the consumption pattern of the society.

In view of the facts that the direction of technical change in agriculture is not exogenous, but depends on the steps taken by the public sector and that such technical change may have different effects on different facets of the society, the public sector should take the question of allocating funds to agricultural research and extension programmes seriously. This evidently calls for an in depth analysis of the subject matter and it is to this that the study presented in this dissertation is addressed.

I.2 Importance of the Problem

The problem of establishing priorities in the allocation of funds to research and extension activities in agriculture and of analysing the concomitant effects thereof assumes a high degree of importance on several counts.

First, even without conforming to the doctrine of agricultural fundamentalism, we can recognize the importance of developing agriculture for the overall development of any economy.2 Stated briefly, the agricultural sector supplies the vital raw material for the industrial sector, serves as a market for it, helps earn valuable foreign exchange for the country, and provides some of the basic necessities of life such as food and clothing. The degree and intensity with which these roles are fulfilled may vary from country to country but these are the basic functions traditionally performed by the agricultural sector in most of the countries of the world.

Second, there exists a huge technology and productivity gap between the developed and the developing countries of the world in the realm of agricultural production. In many instances, the productivity of the former exceeds that of the latter by more than two hundred per cent.3 Ironically, the developing countries are also characterized by a high rate of population growth. As a result, these countries face the uphill task of multiplying their agricultural productivity for maintaining the current level of consumption for the ever-growing population and also for striving toward the levels attained by the countries already developed.

Third, although some developing countries have realized this problem, and stepped into an era of agricultural research and extension programmes, available evidence suggest that such investments are quite low compared to the needs. In addition, it is possible that much of this investment is wasted due to the absence of priority considerations in crop selection and due to the duplication of services. The main reason for this inadequate and misdirected investment is that these countries jumped into the task of allocating research and extension funds without any sound ex ante analysis.4 The situation in most of the developing countries in this respect is aptly described in the observation made by Helleiner (1977): "In many less developed countries, the possibilities of raising capital either at home or abroad now look less daunting than the problems associated with technological progress".5

Fourth, the problem gets added importance on account of the fact that so far very little work has been channelled in this direction. The literature of economic science is quite poor as far as studies concerning the allocation of research and extension funds in agriculture are concerned. Similarly, our knowledge about various aspects of technical change is still at an early stage of development. Not long ago, Bonnen (1970) observed that very little is known about the process by which technological change works its distributional effects and that the existing institutional arrangements to contend with the problem are highly inadequate. Even though the decade of the seventies has witnessed a resurgence of interest in the study of agricultural development the conclusions of Bonnen are still quite valid.

Finally, the significance of the problem is enhanced by the fact that the issue is highly volatile and can generate considerable social tension. The public sector must be aware of various socio-political implications of any step taken by it. If technical change in agriculture sponsored by the public sector goes on favouring some particular group of people at the cost of another, a growing discontent may mount up. Pinstrup-Anderson (1974) observed: "...a strong belief developed that the technology brought about through agricultural research tended to benefit the higher income groups in the society, hence aggravating the skewed income distribution currently found in most of the developing countries".6 Recent studies of Grabowski (1979) and others lend support to this view.[7] Similar problems are surfacing in the developed countries as well and are manifested by the recent demonstrations of U.S. farmers against falling farm prices emanating from technical change in agriculture. All these illustrate that the neglect of the distributional aspects of technological change may have far-reaching consequences and may even lead to self-degeneration of the entire programme.

1.3 Organization of the Study

The study is divided into seven chapters apart from an appendix and a bibliography. Chapter II presents a discussion of induced innovation in agriculture keeping an eye on both the theoretical and the empirical developments of the concept. It also draws our attention to the importance of the role played by investments in research and extension programmes in developing the agricultural sector. The analysis of the chapter is complemented by that of Chapter III which presents a deeper study of induced innovation in agriculture with reference to today's developing countries. The conclusions of this chapter are also tested empirically with the data of the agricultural sector of Bangladesh. Chapter IV clarifies some of the basic concepts used in the text. It also seeks to justify the need for public sector intervention in agricultural research and extension programmes. A guiding model for the public sector for determining agricultural research resource allocation and for analysing its consequences is developed in Chapter V. In Chapter VI estimates of the parameters of the model are presented. These estimates are based on the data from Bangladesh. Finally, the major findings of the study in the context of Bangladesh and its general limitations are discussed in Chapter VII, which also carries a brief summary of the entire study.

FOOTNOTES TO CHAPTER I

1. There are several ways of citing a reference material. The general method followed in this study is to present its year of publication within parenthesis at the first instance any study is cited. For subsequent citations of the study in the same chapter the year has not been mentioned. If the study is cited in any other chapter afterward, it has been identified by the term "op. cit." within parenthesis during its first introduction in the chapter. However, while citing a source material in a footnote or in a Table, the year of its publication has been included for convenience.

2. The doctrine of agricultural fundamentalism states that the agricultural sector is the fundamental sector in any economy and that if it is developed the rest of the economy will develop automatically. For a detailed discussion of the idea see Black (1953).

3. For specific instances of the yield gap between the developed and the developing countries, the reader is referred to various issues of the Production Yearbook published by the Food and Agricultural Organization, Rome (henceforward referred to as F.A.O.).

4. The argument is developed on the basis of similar experiences in Bangladesh and Brazil which, we believe, are representative of other developing countries.

5. See Helleiner (1977), p.295.

6. See Pinstrup-Anderson (1974), p.1.

7. Some of these studies are briefly discussed in Chapter II.

CHAPTER II

SURVEY OF THE LITERATURE ON INDUCED INNOVATION WITH SPECIAL REFERENCE TO THE AGRICULTURAL SECTOR

II.1 Introduction

The primary purpose of this chapter is to present an analysis of the theoretical and empirical work on induced innovation keeping the agricultural sector in the focus of attention.1 The subject matter of induced innovation has a long history, but very recently it has drawn a great deal of attention, and is developing quickly. On the empirical side, the nature of induced innovation in the agricultural sector experienced by the countries where formal tests for it were applied shows considerable variation from country to country. The chapter concludes with an attempt to explain these observed differences. It is suggested that variations in the levels of expenditures on indigeneous research and extension activities in agriculture **may be** a possible contributory factor to variations in the achieved levels of induced innovation. The next chapter develops a more elaborate analysis of the forces behind induced innovation which, it is hoped, can be used to provide a more precise interpretation of the phenomenon.

The chapter is divided into five sections. Section II.2 presents a brief survey of the theories of induced innovation while the empirical application of these theories is discussed in Section II.3. An attempt is made in Section II.4 to explain the observed variations in the levels of induced technical change in agriculture achieved in different countries. Finally, a summary of the chapter is presented in Section II.5.

II.2 Theories of Induced Innovation

The theories of induced innovation owe their origin to the analysis of factor shares and biases in factor saving emanating from technical change.2 We can regard the biases or the rate of technical change as a phenomenon determined from outside the system. However, to consider technical change as completely exogenous restricts the analysis. One can introduce more flexibility into the horizons of technological possibilities by recognizing the fact that endogenous factors are capable of influencing, either partially or fully, the factor saving biases and the rate of technical change in any given period. Given a certain amount of research expenditure, it may be possible to develop a large variety of processes each with a different impact on the cost of production and factor intensities. This kind of approach, in essence, leads us to the development of an investment-theoretic approach to technical change usually discussed under the banner of induced innovation.

The idea of induced innovation was first developed by Hicks (1932). In his view, changes in factor prices will induce biases that lead to a saving of the more expensive factor in a progressive way. He, however, refrained from specifying the mechanism by which the entire process would work. His main purpose was to employ the concept to explain the observed constancy of the relative shares of factor incomes in a neo-classical framework.

Salter (1960) criticized the Hicksian view of induced innovation by maintaining that the Hicksian model is devoid of any mechanism through which the postulated investment may take place. He makes a distinction between basic scientific knowledge and its applied or engineering counterpart. In his view, induced innovation implies the development of the former, not the latter. He then argues that firms will not be motivated to develop new knowledge thereby enabling induced innovation to take place for

> "If ... the theory implies that dearer labour stimulates the search for new knowledge aimed specifically at saving labour, then it is open to serious objections. The entrepreneur is interested in reducing costs in total, not particular costs such as labour costs or capital costs. When labour's costs rise, any advance that reduces total costs is welcome, and whether this is achieved by saving labour or capital is irrelevant. There is no reason to

> assume that attention should be concentrated on labour-saving techniques, unless, because of some inherent characteristic of technology, labour-saving knowledge is easier to acquire than capital-saving knowledge".[3,4]

Salter recognizes the possibility that the directions of applied knowledge may be steered by the movements in relative factor prices. But changes in applied knowledge do not qualify to be termed as induced innovation in accordance with his definition. It follows, therefore, that the criticisms of Salter are based on the semantics of defining induced innovation.[5]

Fellner (1961,1962) provided further support for the main thread of Salter's argument. He, however, pointed out that if we substitute the expectation of a change in factor prices for the actual changes in the relative factor prices in the past as the basis of decision, we get back to a theory of induced innovation similar to that of Hicks.

Ahmad (1966,1967a,1967b) rescued the Hicksian theory of induced innovation from Salter's criticisms and provided the vitally important micro-foundation to the concept. He pointed out that the criticisms of Salter were tautological, as he had simply defined induced innovation out of existence. Ahmad further argued that the perspective of Fellner was unduly pessimistic and showed that by generalizing Fellner's own technique it was possible to provide an analytical basis for the Hicksian theory.

Ahmad's analysis is based on the concept of a historic innovation possibility curve (henceforward referred to as IPC) and is described below. Suppose at a given time the entrepreneur faces a set of potential production processes to be developed which may be regarded as the state of basic sciences. It is assumed that each process in the set is characterized by an isoquant with a relatively small elasticity of substitution and that each of the processes in the set requires a given amount of resources to be developed to the point where it can actually be used. The IPC is defined as the envelope of all unit isoquants of the subset of those potential processes which the entrepreneur might develop with an exogenously given amount of development expenditures. The potential rate of technological change is, therefore, given exogenously. His idea can be expressed with the help of the following figure:

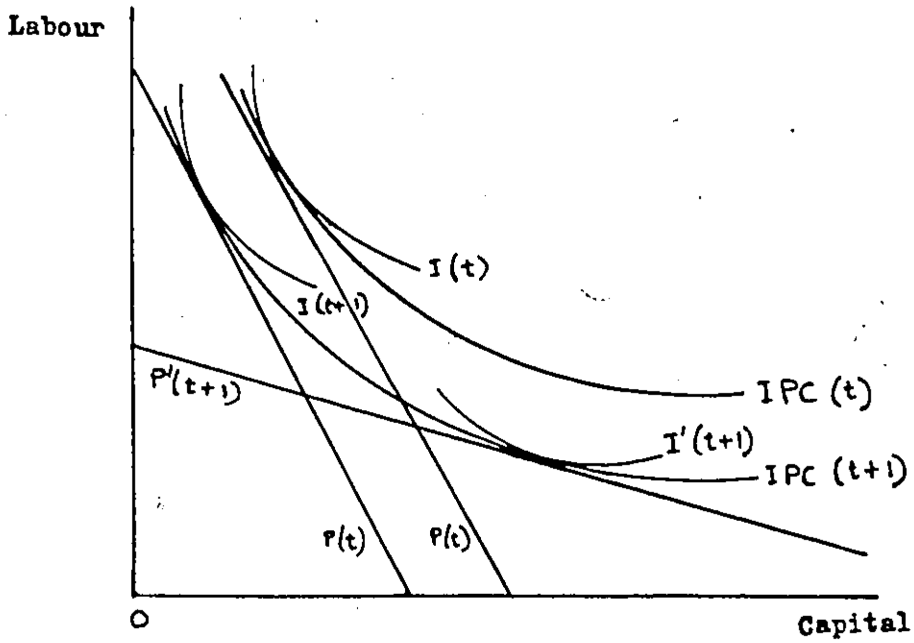

Figure 2.1 Ahmad's Induced Innovation Theory

For period t the process I(t) had been developed, the corresponding IPC being IPC(t). Given the relative factor prices shown by the line P(t), this process is the cost minimizing one. Once I(t) is developed, the rest of its IPC loses significance because for the next period the IPC has shifted inward to IPC(t+1). If relative factor prices do not change, entrepreneurs will now develop the process I(t+1). If the IPC shift inward neutrally, technical change will be neutral at constant factor prices. It is also possible that the IPC may shift inward non-neutrally giving rise to biases even if relative factor prices do not change. Now if the factor price ratio changes to P'(t+1), it is no longer optimal to develop I(t+1) and the process I'(t+1) becomes optimal. The way Figure 2.1 is drawn, P'(t+1) corresponds to an increase in the relative price of labour. Then, given a neutral shift of the IPC, I'(t+1) will be relatively labour saving compared to I(t).

Assuming that research cost is zero and that the entrepreneurs have full information about factor prices and possible alternative processes, the occurence of induced innovation is ensured by the way in which the IPC is defined. Toward the end of his original article, Ahmad has shown that for a country faced with three alternatives, namely, not to innovate, innovate through borrowing technology and innovate through indigeneous research, the potential loss will be greatest for the first situation followed by the second.

Ahmad's model was developed within the context of a market-oriented production or research structure and at a high level of aggregation, since the IPC includes the total stock of scientific knowledge within the economy. In this context it should be noted that his model does not consider the possibility of spending resources to influence the shift of the IPC. Another major limitation of his theory is that it does not take the cost of developing the technologies into account. If the net gain from developing a technique is negative (i.e., benefits are less than the costs), no entrepreneur will wish to develop the new technique.6

De Janvry (1973) has extended Ahmad's model with a view to analyse the technological stagnation in the agricultural sector of Argentina. He explicitly introduced product prices in addition to input prices and developed the upper and lower bounds for a socially optimum equilibrium. Under perfect competition the magnitudes of these boundaries will depend on the ratios between product and factor prices. The equilibrium point emerging in this process is defined by De Janvry as the latent demand for innovations. He showed that government interventions such as tariffs, and the riskiness of the enterprises can shift the latent demand for innovations from the socially optimum path and create a state of technological stagnation.

Like Ahmad, De Janvry assumed that technological innovations can be generated without any cost. But he mentioned that it is possible to relax this assumption. If the costs of research are internalized into the prices of the output, optimal latent demand for technological innovations will shift towards the traditional technologies.

Hayami and Ruttan (1970,1971,1973) also extended the model of induced innovation from a different perspective. Their model is developed at a lower level of aggregation than that employed by Ahmad. In addition, they postulated that the generation and adoption of technology in agriculture materialize through dialectic interaction between the entrepreneurs and the public sector sponsored research organizations. In this respect the Hayami and Ruttan approach can be regarded as an extension of Ahmad's model, since the latter defined induced innovation in a purely market-oriented production economy while Hayami and Ruttan introduced public sector into the model.

Hayami and Ruttan based their model on the concept of a meta production function which can be traced back to the concept of the IPC developed by Ahmad.7 They have defined this function:

> "as the envelop of commonly conceived neo-classical production functions.... In the secular period of production in which the constraints given by the available fund of technical knowledge are further relaxed to admit all potentially discoverable possibilities, production relationships can be described by a meta production function which describes all conceivable technical alternatives that might be discovered"8

The essential elements of their hypothesis is explained with the help of Figure 2.2 below.

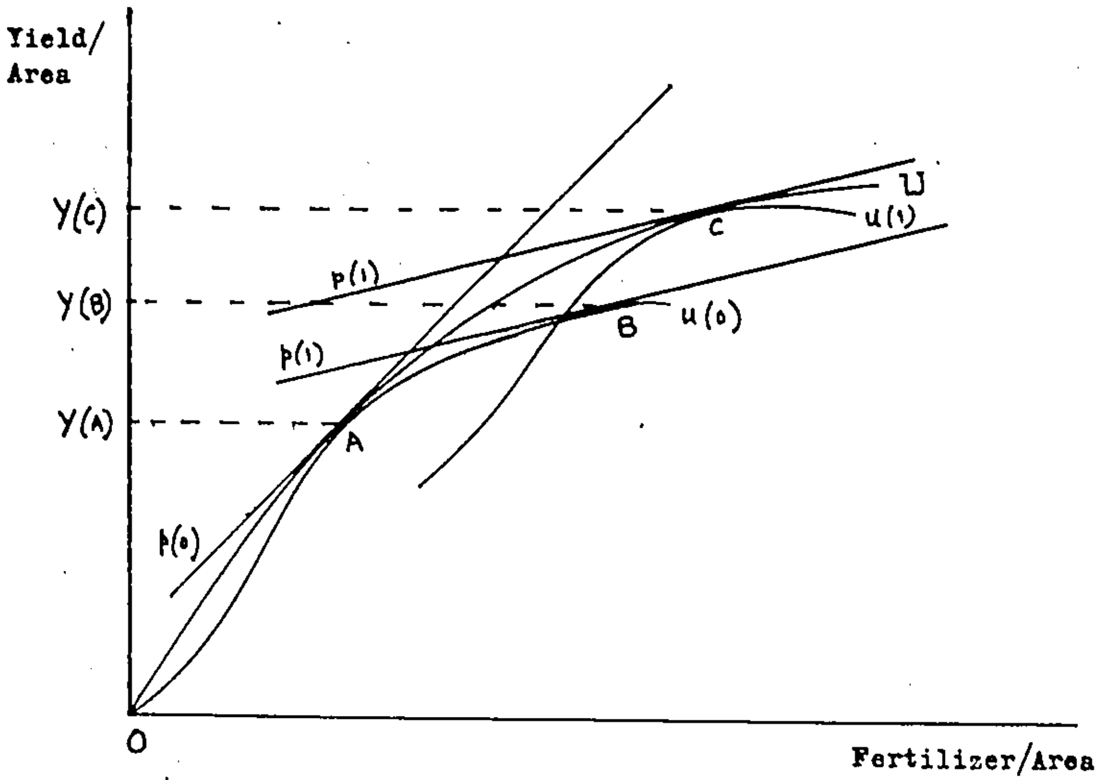

Figure 2.2 Response Along a Meta Production Function

The illustration has been constructed from an assumed advancement in bio-chemical technology. The curves u(0) and u(1) are fertilizer response curves for traditional and the high yielding varieties of any particular crop. A fertilizer response curve shows the different levels of yields obtainable from different doses of fertilizer with the technology remaining constant. U, the envelope of all these curves possesses the characteristics of the meta production function defined above. The optimum variety (i.e., optimum technology) for the crop depends on the prevailing fertilizer-crop price ratio, assuming zero costs for research and extension activities. They are represented by the curves u(0) and u(1) respectively for the price ratios given by p(0) and p(1), and are determined by the highest tangency point between the price line and one of the fertilizer response curves. The most important thing to note is that even if the relative price of fertilizer falls from p(0) to p(1), a movement from u(0) to u(1) does not take place instantaneously or automatically. Such a transition is heavily dependent on the availability of appropriate indigeneous research outcomes and on the provision of various complementary facilities. In the absence of all the ancillary services that come through research and extension activities, the fertilizer response curve u(1) will not be physically available to the economy. In that case the economy remains constrained to the technology represented by the curve u(0). The optimum point in this situation is given by the point B, where the new price line is tangent to u(0). Clearly, the yield advantage from a move from A to B (Y(B)-Y(A)) is quite low compared to similar advantages that could be gained by moving from A to C (Y(C)-Y(A)).

Hayami and Ruttan have claimed that most of the services needed for this transition will be provided by the public sector. They, however, did not formally incorporate the role played by the public sector into the model. In their work, the public sector remains in the background while their explicit model in which only the equilibrium values of the input and the output markets are reflected, appears to be a shorter form of their implicit general model.

The theories of induced innovation discussed so far have one shortcoming in common. None of these explicitly takes the expenditures in research and extension activities into consideration. The credit for formally incorporating this vitally important variable in a model of induced innovation should go to Binswanger (see below) and Evenson and Kislev (1971,1975).9 Evenson and Kislev developed a probability density function for potential yield increases which is assumed to depend on the physical environment, state of basic science and plant breeding techniques. Research is viewed as a job of drawing repeated trials from this distribution. The link with induced innovation is established by identifying the research objective as shifts in the factor demand curves (per unit of output) corresponding to a given production process.10 It is assumed that every research act, if successful, reduces the factor demand by a different magnitude. This enables one to rank the research activities on the basis of their factor saving biases. An investment model is then built in which the entrepreneur choses a portfolio of research activities.

Binswanger (1974a,1978:Chapters 4 and 5) has also reformulated the micro-economic approach to induced innovation by directly introducing both research costs and expected pay-off functions. The main focus of his work is on the process by which innovation is generated. He maintains that the direction of research and hence that of innovation is regulated by three factors, namely, the input prices, the output prices and the structure of the market.

Like Evenson and Kislev, Binswanger also treats research as a sampling process. The expected pay-off from research depends on the first two moments of the sample and on the size of the sample. He observed that the optimal sample size will be higher for industry 'i', if its share in total output is higher. With zero sampling costs research activities will be carried to the point where the marginal benefit from research is zero. A set of such points is defined to be the "scientific frontier". It is interesting to note that the concept of the scientific frontier is very similar to that of the meta production function developed by Hayami and Ruttan. Binswanger mentioned that with positive sampling costs, optimum research will be carried to the point where the marginal benefit from research equals its marginal cost.

In dealing with the directions of research and innovations, Binswanger concluded that from the point of view of a society that wants to maximize income, it makes sense to allocate research resources on the basis of anticipated developments in the goods and factor markets. All of his conclusions remain valid in the context of an individual firm seeking to maximize its own income rather than the income of the society as a whole. Regarding the influence of the market structure, his findings are basically the same as those of Hayami and Ruttan. That is, unless the public sector intervenes, the levels of agricultural research undertaken in any economy will be inadequate and misdirected. Binswanger has claimed that his model is a more general investment model of which the approaches of Ahmad, Hayami and Ruttan and De Janvry are special cases.

The formal model of Binswanger is highly mathematical and abstracts from engaging into a deeper analysis of the question of actual resource allocation among various alternatives. The main reason for this is that once various forces are taken into consideration the model gets quite complicated. The problem becomes more formidable to deal with empirically, because, apart from the question of specification, it also calls for information on a large number of variables, some of which are difficult to quantify. Binswanger mentioned that generally the larger the sector, the more research funds will it command. He, however, observed that : "If technical change is cheaper in a small sector and expensive in a large one, one may want to invest heavily in technical change in the small sector"11.

The question of allocating resources for research had also been the concern of Abel and Welsch (1977). Their analysis is based on graphic exposition only and aims at investigating how the relative factor endowments of a region or a country are likely to affect the allocation of research resources to products with different labour and capital intensities. They found that, in the absence of any commodity bias in the research possibilities, the capital-intensive region should allocate more research resources to the capital-intensive product than to the labour-intensive one, and the reverse should be true for the labour-intensive region.

From the brief survey presented above it appears that although the concept of induced innovation was introduced long ago, it has developed rapidly in recent years. Economists have worked on different aspects of the problem. Nevertheless, the subject has not been developed to its fullest extent. In particular, there is a great need for introducing the costs of research into the framework of analysis, especially from an empirical point of view. Despite the above limitations, considerable amount of empirical work has been done with the existing structure of the concept. This work is reviewed in the next section.

II.3 Empirical Studies of Induced Innovation

II.3.1 Introduction

The theories of induced innovation discussed in the preceding section have been used by many economists for empirical analysis of both the manufacturing and agricultural sectors of developing economies. While most of these studies were concerned with innovations on the input side, some have tried to explain innovations embedded in the form of final goods. In this section we shall focus on both of these approaches. The section is divided into three parts. Empirical studies of induced innovation on the input side are discussed in Subsection II.3.2 while Subsection II.3.3 is concerned with induced innovation resulting from changes in the conditions of final demand.

II.3.2 Induced innovation in the factor market

The formal data-based study of input-oriented induced innovation started with a visible bias towards the manufacturing sector and can be found in the works of Nelson (1959) and others.12 Until 1970, there were no studies testing the induced innovation hypothesis for the agricultural sector of an economy. The reason for the absence of any empirical work in this area is difficult to explain. It is possible that a suitable theoretical framework capable of dealing with the special problems of the agricultural sector was not available before Ahmad's reformulation of the theory of induced innovation. The special problems of agriculture which reduce the incentives of the private sponsors of agricultural research and call for public sector support are discussed in Chapter IV. The meta production function of Hayami and Ruttan, based on Ahmad's innovation possibility curves, provided a method of incorporating public sector sponsored research activities, which play a key role in induced innovation in agriculture. For the convenience of exposition, we have presented the subsequent analyses of this subsection under three separate headings. The first one incorporates the tests of induced innovation carried in a Hayami-Ruttan framework, including their own pioneering work. Several alternative tests of induced innovation developed by Binswanger are reviewed next. The final part focuses on a few related empirical studies on induced innovation from a different perspective.13

A. Tests based on Hayami-Ruttan framework

We begin this survey by presenting a detailed analysis of the original empirical work of Hayami and Ruttan. The importance of their work in the context of induced innovation in agriculture is great as it initiated many subsequent studies, including the present one. The theoretical basis of their work has been discussed elsewhere in this chapter. Empirically, they compared agricultural time series data on labour, land and machinery productivity in Japan and the U.S.A. and from additional evidence of fertilizer use, they concluded that both countries had experienced biased efficiency growth in agriculture. The differences in the development of these series between the two countries are quite high. This fact tends to suggest that they must originate from biases in different directions rather than from the simple substitution of factors along the production function of a neutrally changing individual production process.

An important assumption of the Hayami-Ruttan proposition is that at each moment of time the elasticities of substitution among factors of production in agricultural activities are small enough to justify a near-fixed-proportions production function. This contention is supported by the experimental studies on fertilizer response which show that the optimal fertilizer use in each crop does not change significantly with changes in prices. Similar examples for mechanical processes such as harvesting of grain are also presented by the authors.

Once it is accepted that there exists a near-fixed-proportions type production process, the test of the induced innovation hypothesis from time series data takes the following form. First, one has to estimate the ex post elasticity of substitution between various factors of production from observed data. A large value of this parameter will, then, indicate the occurence of biased technical change since it is believed to have a low value along a given production function. The advantage of this method is two-fold: first, it is possible to prove the endogeniety of biases, and second, it acknowledges the importance of the role played by factor prices in shaping the nature of innovations.

For both Japan and the U.S.A., Hayami and Ruttan used land-labour, power-labour and fertilizer-land ratios as the dependent variable of regression. The regressions with the first two variables represented the state of the mechanical technology while the remaining one stood for the bio-chemical technology. Each of these dependent variables were, then, regressed separately on various factor price ratios using the technique of multiple regression analysis. In the absence of adequate theoretical knowledge, a priori, they specified the regressions in log-linear form.[14]

For the sake of brevity, we have refrained from presenting a detailed analysis of their actual empirical results.[15] Stated briefly, their results indicate that in the U.S.A. variations in relative factor prices were capable of explaining more than eighty per cent of the variations in the land-labour, power-labour and fertilizer-land ratios. Almost all the coefficients had the proper signs and were statistically significant. From these results one may conclude that the changes in factor proportions in the U.S.A. during the period 1880 to 1960 (their period of coverage in the study) were influenced by changes in relative factor prices.

In the case of Japan, the results of the test showed a somewhat mixed response. The statistical quality of the equations in terms of explanatory power and the expected signs of the coefficients were relatively poor for the land-labour and the power-labour equations. However, the performances of the equations involving the fertilizer-land ratio was highly satisfactory by the same criteria. This carries an interesting implication for a country which places less emphasis on indigenous research activities. Japan is a land-scarce and labour surplus country relative to the U.S.A.16 During her early phases of agricultural innovation, she realized this feature and applied more stress on research leading to land saving technologies. Her interest in labour saving technologies were manifested at a much later stage.17 As a result, the emphasis placed by Japan on research leading to mechanical innovations was considerably less, compared to research aimed at bio-chemical and agronomic innovations. This leads us to make an important observation that in the absence of successful and adequate research activities undertaken indigeneously, the responses to be expected from any test of induced innovation in agriculture should not be very good.

The framework of analysis introduced by Hayami and Ruttan has been used by several other authors in different contexts. Wade (1973) has applied the Hayami-Ruttan type test to the agricultural sectors of Denmark, France and the U.K., while Weber (1973) did the same thing for Germany. In another related work, Ruttan, Binswanger and Hayami (1977) have extended the period of coverage of the Hayami-Ruttan type test to the agricultural sectors of Japan and the U.S.A. from 1880-1960 to 1880-1970. The authors compared the new results with those of the original work and also with the works of Wade and Weber.

Briefly speaking, the responses observed from the equations for bio-chemical technologies were very encouraging as all the variables had proper signs and the explanatory power of the regression equations was greater than fifty per cent with the sole exception of the equation for France. In particular, the coefficients of the fertilizer-land price ratios were highly significant in explaining changes in the amounts of fertilizer used per unit of land and all had proper signs.18

On the other hand, the equations for mechanical technology did not behave as nicely as those for bio-chemical technology. In general, the performances were better for the equations pertaining to the U.S.A., the U.K., and Germany where they revealed an explanatory power in excess of fifty per cent with proper and significant signs for the parameters.19 However, the same thing did not happen for the corresponding equations for Denmark, France, and Japan. The authors attributed this to a poor inducement mechanism for mechanization in an environment characterized by low wage rates.

The application of the Hayami-Ruttan type test discussed so far focused on countries with currently developed agricultural sectors. Ahmad and Kubursi (1979) have applied a similar test to the agricultural sectors of two developing countries, Egypt and Syria. These two countries reflect considerable differences in factor endowments which makes this study comparable to that of the original work of Hayami and Ruttan. Their main interest was to determine:

> "(i) Whether or not Syria's and Egypt's agricultural factor proportions have responded to their relative prices.
>
> (ii) Whether or not the pattern of response, if it exists, is similar to Japan's or to the U.S.'s.
>
> (iii) Whether or not their responsiveness has led to increases in agricultural productivity...."20

The most interesting aspect of their study is the introduction of the concept of "Induced Adjustment" in place of induced innovation. The former, according to the authors, takes account of both ordinary factor substitution due to changes in relative prices as well as the effects on factor proportions due to innovation. However, if the production situation is characterized by near or almost fixed proportions, as contended by Hayami and Ruttan, the amount of factor substitution due to changes in relative prices will be negligible and the differences between these two measures will not be very large.21,22

In their empirical analysis, the authors were faced with the problem of non-availability of land price series. This prevented them from obtaining results which require land-labour price ratios for their calculation. They also argued that in developing countries where agricultural population is increasing at a rapid rate with little scope for their absorption outside agriculture and where the supply of agricultural land is relatively fixed, the land-labour ratio may be treated as an exogenous variable. Ahmad and Kubursi used the land-labour ratio as both exogenous and endogenous in alternative equations, but the results were not conclusive. The treatment of the land-labour ratio as exogenous improved the explanatory power of the equations for Egypt but reduced the explanatory power of the equations for Syria, with little effect on the signs of the independent variables. The overall response for both the countries was not very good while the relative performance was better for Egypt, a result which the authors argued might be a reflection of better water supply in that country.

B. Tests of induced innovation a la Binswanger

Binswanger (1973) has criticised the Hayami-Ruttan type test on the ground that this does not represent an adequate test of the induced innovation hypothesis. His main argument is that this test does not distinguish between factor substitution due to changes in relative prices and variations in factor proportions caused by shifts in the production function. To remedy the shortcomings Binswanger suggested two alternative tests of induced innovation. The first one, known as the two-factor test, proceeds in two steps. The first step involves the calculation of the "necessary elasticity of substitution" defined as a value that can explain the observed factor-ratio differences by differences in factor price ratios. These "necessary elasticities of substitution" are then compared with econometrically estimated elasticities of substitution. If they differ by a sufficiently large margin, the hypothesis of neutral technical change can be rejected. The rationale for the two-factor test and the methodology used for estimating pairwise elasticities of substitution are discussed in the third chapter of Binswanger and Ruttan (1978).

The test was applied to the same six developed economies for which the Hayami-Ruttan type tests had been conducted by various authors and the results are reported in Ruttan, Binswanger and Hayami and also in the third chapter of Binswanger and Ruttan. It was found that the overall results were consistent with the induced innovation hypothesis. The authors also focused on the possibility that two types of biases might distort the pattern of innovation. These are defined as the fundamental bias and the transfer bias. The former refers to the bias emanating from the nature of the existing stock of knowledge while the latter incorporates the bias inherent in importing technology from a country with different relative factor endowments.

One major limitation of the two-factor test described above is that in this test a many-factor production process is treated as if it were a two-factor process. As a result the influences of many important factors of production had to be inadvertently neglected. To overcome this Binswanger (1974a,1974b,1978:Chapter 7) also developed a many-factor test of induced innovation which is based on directly measured biases in the direction of technical change in the use of individual factors rather than on ratios of factors. The essential elements of the test involved partitioning the observed changes in factor shares into a component due to ordinary factor substitution and a component due to bias in the direction of the technical change. To achieve this, elasticity of substitution parameters were to be estimated from an independent sample. Next, these parameters were used to adjust the time series data on factor shares changes to obtain the part that was caused by the technical change alone. At the end, the job becomes one of comparing the turning points in the price corrected factor shares series with those in the series of factor prices. The existence of induced innovation will be established if the former follows the latter after a lag of several years. Empirically, the test was applied to the agricultural sector of the U.S.A.[23] Binswanger found that the results of the many factor test were fully consistent with the induced innovation hypothesis. The major problem with this test is that it depends on highly sophisticated time series data which prevented him from applying the test to Japan.

C. A different view on induced innovation

A recent work by Grabowski (op. cit.) supports the views of Hayami and Ruttan and De Janvry regarding the dialectic interaction between farmers and research organizations. Grabowski advances the hypothesis that in the developing countries, in particular, rich land-owners are in a position to exert more pressure on the research centers. This is likely to bias the output of research activities towards the development of labour saving inputs which tends to favour the large land-owning class. The author presents evidence from India and Malayasia in support of this claim.[24] According to Grabowski, the introduction of labour saving innovations may prove to be self defeating, as these innovations will hardly generate any additional employment in the agricultural sector. The effective demand for agricultural products will be depressed due to this which will eventually lower the prices of agricultural products. Grabowski mentioned that the ideal solution in such a situation is to implement extensive land reforms which would reduce the power large land-owners have had in affecting the directions of research in the developing nations.

The income distribution aspect of induced technical change in agriculture has drawn the attention of other authors as well. Staub and Blase (1973) have discussed similar problems and observed that if the governments of the developing countries provide adequate credit to small farmers, they will respond by adopting new technologies to the same extent as the large farmers, thus eliminating the effects of big farmer bias in research activities. Uphoff and Ilchman (1972) have suggested another positive way to eliminate this bias in research. They suggested that the government should provide the leadership in organising small farmers and rural labourers so that they are able to influence the direction of research. A technology consistent with an employment or equity oriented strategy of development, which appears to be the only consistent means of promoting self-reinforcing growth, could then be developed through research.

The last two studies cited above draw our attention to the institutional, rather than technological, aspects of induced innovation. Working along this direction Feeny (1976) has shown that it is possible to extend the

Hayami-Ruttan framework of anaysis by incorporating a supply and demand model of technical and institutional change. His model explicitly considers the net benefits to decision makers as arguments in the supplies of technical and institutional change. Feeny applied the model to the agricultural sector of Thailand to explain the changes in Thai institutions in response to changing factor prices. In a recent article Feeny (1979) carried his argument further and suggested a solution to the problem created by agricultural dualism as pointed out by Grabowski. If such dualism exists, the appropriate institutional innovation according to Feeny is to increase political power for the rural poor. The concept of institutional innovation can be traced back to Ruttan (1971). In this article Ruttan acknowledged some of the inadequacies of the Hayami-Ruttan approach to induced innovation and went on to observe that environmental services are traditionally undervalued. He believes that such undervaluation will bias the direction of induced technical change towards excess residual production. Ruttan suggested the extension of the theory of induced innovation to include the process of institutional innovations capable of establishing property rights with respect to environmental subsystems. Clearly, the theory of induced institutional innovation complements the traditional approach to the theory of induced innovation which focuses on the technological aspects only. In a subsequent study, Ruttan (1978) analysed the development of the theory of induced institutional change and concluded that this theory, like the conventional theory of induced innovation, is still incomplete.

II.3.3 Induced innovation in the product market

The major thrust of the theoretical and empirical work on induced innovation was to explain the influences of resource endowments and factor prices on the direction of technical change. However, there have been several studies of induced innovation focusing on the conditions of final demand. Griliches (1957) made a study of hybrid corn in the U.S.A. and demonstrated the importance of demand in determining the location and diffusion of new hybrid corn varieties. Schmookler (1966,1972) also studied the link between demand conditions and technical change in several industries of the U.S.A. which included agricultural equipment industries. He observed that the expected rate of return to inventive activity was of far greater importance than advances in the state of knowledge in explaining the technical change.

At the macro-economic level, Lucas (1967) analysed the rate of technological advance in the manufacturing sector of the U.S.A. Using quarterly data for 1947-60, he was able to confirm the responsiveness of technical change to the conditions of final demand. Another study by Ben-Zion and Ruttan (1978) also focused on the effects of demand forces on the nature of technical change. Working with the experiences of the U.S. economy during the period 1929-69, they found that the rate of input saving technical change was higher in periods of growing demand than in periods of stable or declining demand in the economy of the U.S.A.25

Thus far in this section we have found that formal tests of induced innovation in agriculture have been applied to eight countries of the world in different contexts. These are Denmark, Egypt, France, Germany, Japan, Syria, the U.K. and the U.S.A. One interesting feature of these tests is that except for the study of Griliches, all other studies emphasize the input side of innovation. These tests indicate marked differences in the nature of induced innovation experienced by these countries. While the levels of induced technical change achieved by some countries were quite high, they were not high for the others. In the next section, we intend to provide an explanation for these diversities by focusing on one major constituent of induced innovation: the levels of expenditures on indigeneous research and extension activities. Although our study does not intend to underemphasize the role of induced innovation on the product market, the analysis of the next section could not be extended to incorporate such innovations. The reason is obvious and explained above: the virtual absence of any empirical work on this area for the agricultural sector. Nevertheless, in the subsequent chapters of the thesis the question of induced innovation based on final demand conditions will be given its due attention as far as possible. In particular, in the development of the ex ante model for resource allocation for agricultural research and extension activities, we shall focus on both input and output prices as integral parts of the process.

II.4 Induced Innovation and the Levels of Expenditures on Agricultural Research and Extension Activities

In the preceding section we have observed that the achieved levels of induced innovation in agriculture were disproportionately spread among different countries. The purpose of this section is to suggest that this variation may be attributable to the extent in which indigeneous research and extension activities in agriculture were carried out in these countries. Due to the lack of adequate data, our conclusion in this section lacks precision and can only be interpreted as an indicator of general directions.

Table 2.1 below ranks the eight countries mentioned before in terms of their respective levels of performances in the tests. The countries were first divided into two groups: good and poor. The former included the countries for which the coefficient of determination of the respective equation was greater than fifty and all the explanatory variables had statistically significant coefficients with proper signs. Countries which failed to satisfy the above criterion were categorized under the latter. In addition, a ranking was established among the "good" countries on the basis of the value of the coefficient of determination.

TABLE 2.1

RELATIVE PERFORMANCES OF THE COUNTRIES IN THE TESTS FOR BIO-CHEMICAL AND MECHANICAL INNOVATIONS

Bio-chemical		Mechanical	
Japan	(G)	Germany	(G)
U.S.A.	(G)	U.S.A.	(G)
Germany	(G)	U.K.	(G)
U.K.	(G)	Japan	(P)
Denmark	(G)	Denmark	(P)
France	(P)	France	(P)
Egypt	(P)	Egypt	(P)
Syria	(P)	Syria	(P)

Source: Hayami and Ruttan (1971); Wade (1973); Weber (1973); Ahmad and Kubursi (1979); and our estimate.
G: Good; P: Poor

In order to interprete these diversities in attaining induced technical change by various countries in the light of expenditures on indigeneous research and extension activities, it is necessary to have detailed information on these variables for each of the countries under study. This proved to be a formidable task and the only statistical information that could be obtained readily were those reported in Evenson and Kislev (1975), which only covers the year 1965. In the absence of any other information we used the figures for 1965 with the assumption that the ranking of the levels of expenditures on agricultural research and extension relative to agricultural GDP and arable land in 1965 are representative of these rankings in other years as well. Table 2.2 shows the levels of expenditures made by each country on indigeneous agricultural research and extension in the year 1965, in absolute terms, as a fraction of gross domestic product in agriculture in 1965, and as a ratio to the amount of arable land available in the year 1965.

TABLE 2.2

EXPENDITURES ON RESEARCH AND EXTENSION IN AGRICULTURE, 1965

(in U.S. Dollars)

Country	Total Expenditure (TE) (in thousands)	TE/GDP in Agriculture (in percentage)	TE/Arable Land ($/hectare)
Japan	$ 98,810	1.55	16.46
Germany	$ 79,031	1.31	9.57
U.S.A.	$528,000	1.22	3.57
U.K.	$ 41,960	1.18	5.60
Denmark	$ 12,384	1.01	4.57
France	$ 63,200	1.04	3.08
U.A.R.	$ 9,200	0.60	3.44

Source: Evenson and Kislev (1975), pp. 166-69; F.A.O. Production Yearbook, various issues; and our estimate.

The data for Egypt and Syria were not reported separately by Evenson and Kislev or by the F.A.O. Production Yearbooks as they were united under the U.A.R. in 1965, which included Libya as well. Due to the absence of any other data source, we used the data for the U.A.R. taken as a whole.

A careful comparison of Tables 2.1 and 2.2 reveal some interesting results. From Table 2.1 we find that the U.K., the U.S.A. and Germany produced consistently good results in the tests for both types of induced technical changes, namely, bio-chemical and mechanical. The data on Table 2.2, on the other hand, indicate that the expenditures on agricultural research and extension in relation to the gross domestic product in agriculture and in relation to the arable land available in the corresponding year were higher in these countries compared to those in most of the remaining ones. An important exception to this generalization is Japan who made a significant investment in agricultural research and extension but showed poor results in the test for induced innovation in mechanical technologies. A possible explanation for this is already given in Section II.3. The relative factor endowment of Japan generated very little inducement for advancements in the mechanical technology and, as such, most of her agricultural research and extension activities were directed towards the bio-chemical and agronomic technologies. The fact that such activities aimed at the bio-chemical technology were highly productive in Japan is indicated from her relative position in terms of the test for induced bio-chemical technical change reported in Table 2.1. Similarly, the overall performances of the remaining countries, Denmark, Egypt, France and Syria were not very satisfactory according to our criterion. This is also consistent with the fact that relative levels of expenditures on agricultural research and extension were also generally low for these countries, as seen from Table 2.2.

The implication of the above findings is that successful achievement of induced technical change has some degree of association with the relative levels of expenditures on agricultural research and extension. Research and extension activities in agricultural are receiving increased recognition as productive economic forces and occupy a central position in the study of induced innovation in agriculture. The following chapters of our thesis aim at developing this same theme with special reference to the agricultural sector of Bangladesh.

II.5 Summary of the Chapter

This chapter has presented a fairly detailed survey of the existing body of knowledge on induced innovation in the context of the agricultural sector. The relationship between induced technical change in agriculture and the concomitant growth of the sector is not discussed in the thesis. It is the premise of the entire study that induced innovation in the agricultural sector is synonymous with the growth of that sector. Focusing on international differences in agricultural productivity, Hayami and Ruttan

(1971) have provided conclusive evidence in its support.26 Our main interest lies on the factors influencing the nature of induced innovation in agriculture. We have observed that the levels of induced technical change achieved by various countries differ quite significantly. Based on the limited statistical information available, we were able to suggest that such differences might be explained by the variations in the levels of indigeneous research and extension programmes pursued by these countries. In general, countries placing higher emphasis on agricultural research and extension services also showed higher levels of success in achieving induced innovation in agriculture.

It was also found that the role of research and extension activities has been neglected in the analysis of induced technical change in agriculture. Though some attempts have been made recently to incorporate this role in a theoretical framework, these models are not easily amenable to empirical application.

Traditionally, the literature on induced innovation developed by analysing the consequences of changes in factor prices on the biases in technical change. However, we have observed that the conditions of final demand are also capable of exerting influence on the nature of the bias and on the directions of technical change. In fact, the trends in both the factor and the product markets are important in explaining the induced bias in technical change and neither of them should be neglected.

Finally, another important finding of the chapter is the fact that technical change in agriculture might be related to the problem of inequitable distribution of income. This raises the familiar issue of growth versus equity considerations in development economics, an issue which is beyond the scope of the present study. Nevertheless, it follows that distributional questions cannot and should not be ignored in any discussion of technological change and growth.

The findings reported above constitute important elements of the present study. The allocation model developed and implemented in the later chapters views agricultural research and extension activities as a major factor in induced technical change in the agricultural sector. Our study does make some contribution to the discussion of the distributional aspects of technological change in agriculture. With the aggregate data available to us, we are able to analyse the distribution of benefits of technical change in agriculture between consumers and producers. Moreover, published micro-level data are utilized to throw some light on the possible patterns of income distribution among factors of production. Regarding the influences of input and output markets on the nature of induced innovation, our study recognizes the importance of both of them. The allocation model, mentioned earlier, considers both input and output prices before suggesting the optimum allocation pattern of resources for agricultural research and extension activities.

To sum up, in this chapter we were able to indicate that expenditures on agricultural research and extension services is a possible contributory factor to induced innovation in agriculture. The analysis of the chapter was based on evidence taken from a cross-country sample. The next chapter develops a formal and detailed analysis of sources of induced technological change in agriculture which is applied empirically to the agricultural sector of a single country, Bangladesh.

FOOTNOTES TO CHAPTER II

1. The terms induced innovation and induced technical or technological change have been used interchangeably throughout the study.

2. In this analysis we refrain from recognizing the distinction between invention and innovation in the Schumpetarian sense where the former stands for scientific and engineering aspects of an improvement and the latter represents its practical application in productive activity which involves socio-economic adjustments. Various authors including Ruttan (1959) maintain that such distinction is devoid of any real meaning.

3. See Salter (1960), pp. 443-44.

4. The "inherent characteristics of technology" referred to by Salter is similar to the concept of "fundamental bias in innovation" developed by Binswanger as described below.

5. In the present study, which follows the Hicks-Ahmad version of induced innovation, this distinction is ignored.

6. In an alternative version of the theory of induced innovation, Kennedy (1964) and Samuelson (1965) proposed to take account of the relative importance of factors, and, in some sense, of the cost of obtaining bias.

7. The difference between these two concepts is as follows: The IPC of Ahmad is developed separately for each period and implicitly assumes fixed research costs while the meta production function of Hayami and Ruttan assumes the maximum possible shift in technology and extends to more than one period.

8. See Hayami and Ruttan (1971), p. 83.

9. Evenson and Kislev (1975) is a collection of separate essays and the model for technological research appears in Chapter 8.

10. The concept is developed from the fact that there exists a duality relation between production and cost functions and that there is one to one correspondence between factor demand curves and cost functions.

11. See Binswanger (1978:Chapter 4), pp. 112-13.

12. Some of the other works in this area are: David and Van de Klundert (1965), Fellner (1971), Asher (1972), Abramovitz and David (1973) and David (1975).

13. The following discussion makes extensive referrence to various types of technological change in agriculture. These types are discussed in detail in chapter IV of the thesis.

14. The regression equations employed by them are similar to those used by us in Chapter III. See equations (3.4) to (3.6) of the chapter.

15. Since this pioneering work initiated many subsequent studies including that of our own, it might be interesting to study their methods and results in details. For this see Hayami and Ruttan (1971), pp. 130-33.

16. Agricultural land area per male worker was .70 hectare in Japan and 25 hectare in the U.S.A. in 1880. In 1960, the corresponding figures were 1.13 hectare and 109 hectare respecteively.

17. Evidence for this is provided by Hayami and Yamada (1968), pp. 135-61 and Ogura (1963), pp. 365-77.

18. The Hayami-Ruttan type tests cited above are also described in Yamada and Ruttan (1975).

19. The only exception to this was the equation with land-labour ratio as the dependent variable for the U.K., for one specific time period.

20. See Ahmad and Kubursi (1979), p. 302.

21. Since the value of elasticity of substitution between factors is not always known, the term "Induced Adjustment" seems proper to use whenever any Hayami-Ruttan type test is applied empirically. We shall try to adhere to this approach in the present study. However, in purely theoretical discussions the terms induced innovation seems appropriate and has been used by us.

22. Incidentally, the distinction between induced adjustment and induced innovation can be linked with the related developments of Binswanger involving the necessary elasticity of substitution.

23. A brief discusion of these two tests and their empirical applications can also be found in Ruttan, Binswanger and Hayami (1977).

24 A study by Ullah (1974) has developed theoretical arguments explaining the reasons for bias of large land-owners towads labour saving innovations. Ullah observed that the bio-chemical technologies in agriculture demands more labour compared with the traditional technologies. This prompts small farmers and share-croppers to allocate more labour to their own land, reducing its supply to the large land-owners. The latter group, therefore, prefers labour saving innovations to land saving ones.

25. Although the manufacturing sector was excluded from our discussion of input-oriented induced innovation we include it in this case because similar studies are absent in the case of the agricultural sector.

26. Nevertheless, indirect support to this contention can be found from our study in Chapter IV, where a comprehensive list of empirical studies has been cited to demonstrate the beneficial effects of investing in research and extension programmes in agriculture. The implicit assumption of most of these studies is that investments in such programmes lead to induced innovation in agriculture, though very few have explicitly recognized it.

Chapter III

INDUCED INNOVATION AND THE AGRICULTURAL SECTOR OF BANGLADESH

III.1 Introduction

This chapter aims at analysing in detail the forces behind induced technical change in agriculture in order to further examine the tests of induced innovation described in the previous chapter. Induced innovation is a multi-dimensional process. Although investments in agricultural research and extension activities (henceforward referred to as AREA)1 is an important element of it, any attempt to explain induced innovation with the help of one factor only, as we did in Chapter II, conceals many of its features. The reason for restricting ourself to a one-factor analysis there was that it would be a major job to analyse all the facets of induced innovation in agriculture in the context of eight different countries taken together. In this chapter we focus on a single country only, Bangladesh. The arguments developed in this chapter can be used to examine the process of induced technical change in agriculture in other countries. The distribution of the contents of the remainder of the chapter is as follows: Section III.2 describes some important sources of induced innovation in agriculture while Section III.3 identifies the major external features associated with any form of technical change. The findings of these two sections are utilized in Sections III.4 and III.5 to analyse the process of agricultural transformation in Bangladesh. A hypothesis is formulated and tested against the empirical data of the country in Section III.6. Section III.7 presents a critical evaluation of the role of the public sector in Bangladesh in certain related fields of agricultural innovations, other than that of sponsoring the research. A summary of the chapter is included in the final section.

III.2 Internal Features of Induced Innovation (With Special Reference to Agriculture)

III.2.1 Economic rationality

Although not mentioned explicitly in most other studies, a strict adherence to the code of economic rationality is the first precondition for induced innovation to take place. Stated briefly, induced innovation is a process through which the economy reaps profit from the opportunities brought before it by the changes in the availability of factor endowments. To perceive these opportunities and to take steps to derive benefits from it, one must behave rationally.

In agriculture, induced innovation specifically requires rational behaviour from two types of agents. First is the rationality of the farmers. The role of farmers in induced innovation in agriculture as presented by Hayami and Ruttan is extremely important.2 In their version of the theory, it is the farmers who first feel the necessity for innovations in the technology which is created by changed circumstances. Through their collective approach this demand is transmitted to the public sector for the sponsorship of agricultural research. In a modified approach to the problem, suggested by the present study and which is more relevant to the developing economies of today, a rational attitude on the part of the public sector itself is also urgently needed for induced innovation in agriculture. As we shall see later in this chapter, in the developing countries the farmers are unable to act in an organized manner due to the absence of appropriate institutional facilities. Under these circumstances, the task of responding rationally to the needs for change falls on the public sector on account of its pervasive role and influences in such economies.

III.2.2 Changes in market conditions

This is another important precondition for induced innovation to take place. Induced innovation, as we have observed, implies adapting to the new situations created by the shifts in the factor or the product markets. Generally speaking, if a factor becomes dearer relative to others, the doctrine of induced innovation calls for developing technologies aimed at saving that factor. Similarly, if the demand for a product increases relative to those for other products, efforts should be made to improve the quality of it through technological advancements. Under competitive situations, movements in market prices can be taken as true indicators of the supply and demand situations for any input or output. The factor becoming scarcer or the product experiencing rising demand will register a steady increase in market price.

Since more than one factor or product can show an increasing price trend at the same time, the theories of induced innovation have been cast in terms of relative prices. Consequently, a steady increase in the price of any input or output relative to that of another input or output respectively can be regarded as the market signal to indicate that a potential demand for induced innovation has been generated.

III.2.3 <u>Public sector sponsorship of AREA</u>

The third important source of induced innovation in agriculture is the willingness of the public sector to sponsor AREA. Hayami and Ruttan have also placed great emphasis on the role of the public sector in equilibrating the supply and demand needs for innovation as the vital factors in the explanation of agricultural productivity.

> "Farmers are induced by shifts in relative prices, to search for technical alternatives which save the increasingly scarce factors of production. They press the public research institutions to develop the new technology and, also, demand that agricultural firms supply modern technical inputs which substitute for the more scarce factors. Perceptive scientists and science administrators respond by making available new technical possibilities and new inputs that enable farmers to profitably substitute the increasingly abundant factor for increasingly scarce factors, thereby guiding the demand of farmers for unit cost reduction in a socially optimum direction".3

The link between the needs of the farmers and its realization by the "perceptive scientists" is created by the dialectic interaction between the farmers and the government in a Hayami-Ruttan model. However, in the developing countries of today, where proper institutional facilities are lacking, it is very difficult for the farmers to put organized pressure on the government. In the context of these countries, the direction of dialectic interaction should be reversed. Rather than the farmers pressing the public sector, it is the public sector who should come forward with AREA and provide it to the farming communities.4

The next chapter discusses in detail the factors that make public sector sponsorship of AREA almost indispensible. Given that the public sector has agreed to sponsor such programmes, the immediate question is whether the outcome of such sponsorship is likely to reflect the needs of the farmers. We can identify three types of situations when this will be so. These are:

(a) When the origins of the government lie in the farm sector, or

(b) When there is dialectic interaction between the farmers and the government, or

(c) When the government in power is responsive enough to realize the appropriate needs of the farmers and takes necessary steps to satisfy those needs.

In the first case, it will be in the private interests of the persons at the centre of decision making to steer the direction of AREA towards the most productive path. For, in such a situation, there cannot be any divergence in the interests between those of the farmers and those of the government. Ayer and Schuh (1972) have shown that the massive investments in cotton cultivation research in Sao Paulo state of Brazil can largely be explained by the fact that the farmers producing cotton were in a position to exert political power during the period when this research took place.

The most illustrative examples of the motivations through dialectic interactions have been provided by Hayami and Ruttan. Dealing with the agricultural sectors of Japan and the U.S.A. they have shown how the farmers of these countries organized themselves into various associations and put pressures on the government at different levels to provide the required research and development services.

Studies describing the third type of motivation, in which the public sector comes forward to sponsor AREA out of its own volition are rare. Nevertheless, this is the most common situation in the countries currently developing, many of whose governments have come to power through non-democratic processes and have little political link with the farmers. The issue of public sector rationality mentioned at the beginning of the section is more relevant in this case because here the farmers and the public sector exist as two distinct entities. Unless both of them act rationally, the achievement of induced technical change in agriculture may be quite difficult.

III.2.4 Actual investments in AREA

This is the most important source of induced technical change in agriculture, but it must work in conjunction with the other forces discussed above. The importance of investing in AREA has been analysed in detail in Chapter II and to avoid repetition, we refrain from discussing this again. The only thing worth mentioning at this point is to re-emphasize the fact that agricultural technology is very much location specific and unless adequate investments are made in AREA, the chances of developing technologies suited to the environment of any region is very remote.

III.3 External Features of Induced Innovation (With Special Reference to Agriculture)

III.3.1 Introduction

The preceding section has described the factors behind induced technical change in agriculture. To achieve induced innovation, it is necessary that all the factors should behave in a positive way. That is, the market trends should favour some particular input or output, both the farmers and the public sector should behave rationally, there should be interaction between them and investments in AREA should be adequate. It is very difficult to determine, a priori, whether all the above forces are behaving positively for any particular country. One possible way to determine this is to analyse the ex post evidences of technical change. Induced technical change is nothing but a form of technical change, and the ultimate test of it must be based on successful demonstration of the fact that a technological transformation has taken place.

Given evidence of technical change, the forces mentioned in Section III.2 can be analysed and, in addition, the tests described in Chapter II can be applied to determine the endogeneity of the technical change. Finally, it should be mentioned that it is possible to get positive indications from the source test based on Secion III.2 but with little or no evidences of technical change. Such an exercise is not entirely fruitless, as it will pinpoint the fact that something has gone wrong in the process and the entire programme of AREA needs a thorough re-examination.

In this section we shall focus on two important criteria to be used to determine the occurrence of technical change. These are: (a) the appearance of new inputs and/or outputs, and (b) an increase in the productivity of the agricultural sector.

III.3.2 Appearance of new inputs and/or outputs

The primary method by which new technology manifests itself is by displaying new kinds of input or output or both. Sometimes these new items may be quite indistinguishable from the old ones in terms of pure physical appearance even though their intrinsic properties are different. A common example for this is seed. Both the traditional and the high yielding varieties of seeds for any particular crop look alike. Unless the appearance of new inputs (we can view new methods, like crop rotation as new input) and/or outputs, which are different from the old ones, either physically or qualitatively or both, can be established, it is not valid to claim that any region or country has experienced induced innovation in agriculture.

III.3.3 Rise in agricultural productivity

As mentioned at the end of Chapter II, the present study assumes that the occurrence of induced innovation in agriculture guarantees a rise in agricultural productivity, though the reverse may not always be true.5 A natural corollary to this is that rise in agricultural productivity is also one of the conditions that must be satisfied before any claim of achieving induced technical change in agriculture can be established.

We see that induced innovation in agriculture is characterized by two types of factors. The first type makes it possible for induced innovation to take place. The second type is the outward demonstration of the fact that the process of induced innovation has become successful. Both of them are useful in the analysis of the subject and may be termed as the "internal" and the "external" features of induced innovation in agriculture respectively. The next two sections focus on the agricultural sector of Bangladesh using this typology as the framework of analysis.

III.4 Internal Features of Induced Innovation : A Case Study of Bangladeshi Agriculture

III.4.1 Introduction

In the preceding two sections we have identified the sources and effects of induced technical change in agriculture. There we argued that any analysis of induced innovation in agriculture must accompany an in depth examination of these factors. In this section we shall study the first of these factors, i.e., the sources of induced technical change in agriculture in the context of Bangladesh. The next section complements it by studying the evidences of such change with a view to arriving at some conclusions regarding the process of agricultural transformation in Bangladesh. This is going to be a long section and is divided into several subsections for expository convenience. Subsection III.4.2 aims at testing the economic rationality of the farmers in Bangladesh while the next one analyses the trends in her factor and product markets. The nature of interaction between the farmers and the public sector and the pattern of investments in AREA in Bangladesh are discussed in the last two subsections.

III.4.2 Test of rationality of the farmers

In the context of the present study, rationality is defined in terms of the positive response of the farmers to the incentives brought before them through changed circumstances. Though relevant, we have refrained from making a test of rationality of the public sector for two reasons: First, it is very difficult to design and implement a rationality test for the public sector as the dimensions of its activities are large in Bangladesh, like other developing countries. Second, a major component of the present study will turn out to be a critical evaluation of the role of the public sector vis-a-vis the agricultural sector of Bangladesh.6 Such an exercise will automatically involve a test of rationality for the public sector and a separate study of the subject is uncalled for.

The estimating equation for the test of farmer's rationality is stipulated in log-linear terms where the ratio of actual land allocation to different crops and the ratio of actual output of these crops are regressed on the ratios of their prices and is described below.

(3.1) $\ln(X/Y) = a + b\ln(PX/PY)$ + error term

where,

X, Y : the acreage under different crops or the actual output of different crops

PX, PY : prices of crops X and Y

a, b : the coefficients of regression.

The objective of the above test is to determine whether the farmer allocates his land between two crops in a way to maximize the net revenue from it, if he is free to do so.7 The equation has been cast under the assumption that every other factor including the costs of production remain the same or have the same quantitative effect on each crop. In the light of recent developments of the theories of farm response, we might argue that the observed price and acreage magnitudes of equation (3.1) should be replaced by the unobserved expected or desired magnitudes.8 However, similar regressions reported in Chapter VI show that for the case of Bangladesh, the naive expectations model dealing with only current quantity and one-period lagged prices had degrees of explanatory power comparable to more sophisticated models.9 As a result, for the sake of simplicity we have used the naive expectations model in the present test.

In the framework of traditional agriculture, the production of any commodity on land infrequently calls for some inputs that cannot be obtained locally.10 Consequently, the farmer is less likely to be constrained to produce any particular commodity and can freely respond to prevalent economic incentives. Moreover, in anticipation of the findings of this chapter, we can state that public sector policies in Bangladesh did little to encourage or discourage the cultivation of any particular crop.11 Under these circumstances, any observed behaviour in terms of the farmers' response or non-response to price incentives can be interpreted as the indicator of his economic rationality. In the context of the present test, the positive response will be manifested by the allocation of more land to the crop (or by the production of more of it through some other means) whose price ratio has become favourable. In other words, a positive coefficient for the ln(PX/PY) term in equation (3.1) will indicate the economic rationality of the farmers in Bangladesh.

Though Bangladeshi farmers produce many commodities on their agricultural land, it is not possible to carry out a test for price-responsiveness involving all of these crops on account of the following factors: (a) reliable price and quantity information are not available for most of the crops for a sufficiently long period of time, (b) most of these crops comprise a very small proportion of the total cultivable land in Bangladesh and, hence, are not of major significance, and (c) these crops do not all compete for the same land at the same time of the year. On the basis of the above considerations, it was decided to focus attention on two crops only, namely, jute and aus rice. Both of these are prominent crops in Bangladeshi agriculture and are also grown in the same season and in similar climatic zones which means that they are directly competitive.12 In addition, we could collect a time series data on these two crops covering a span of more than twenty five years.

Early studies of Sinha (1941) and Shorter (1955) pertaining to the jute growing areas of the entire South Asian subcontinent found evidences of the influence of relative prices on the production pattern of jute and rice.13 Clark (1957) also observed that an increase in rice prices discourages the planting of jute. To be specific, he found that an increase of 50 per cent in rice prices results in an average decline of 180,000 hectares in the jute area in the following season. More recently Hussain (1964) estimated a linear equation in which the proportion of aus and/or aman rice acreage in the total area under aus and/or aman rice plus jute was regressed on the price of rice relative to that of jute. He found that for the whole of Bangladesh (then East Pakistan) the above equation could explain fifty four per cent of the variance. Observing that in certain parts of Bangladesh rice and jute do not compete for the same land due to climatic and physical limitations, he repeated the same study for nine major jute growing districts of Bangladesh. The latter choice increased the explanatory power of the equation to sixty per cent.

The purpose of the empirical results presented in this subsection is to update the works cited above. We wish to find out whether variations in the price of jute relative to that of rice did have any effect on the productive behaviour of the farmers in terms of chosing between these two crops.

As the output of agricultural activities show tremendous fluctuations due to variations in weather conditions, traditionally the supply response of agricultural farmers has been measured from acreage response instead of the response in output. Since the agricultural sector of Bangladesh is still backward in terms of improved irrigation and drainage facilities, the influences of erratic weather are quite heavy on her agriculture. This suggests that acreage would be the best choice as an indicator of farmers' responses to relative price changes. On the other hand, if we assume that the production condition in agriculture is not characterized by fixed coefficients technology, and it is possible to vary the use of inputs on land, the one to one correspondence between acreage and output is destroyed. In that case the latter becomes a better indicator for testing responsiveness. In this study, we have decided to try both acreage and output as dependent variables, keeping in mind that neither jute nor aus rice has shown any evidence of technical change in production and, as such, the acreage response model is expected to yield better results.

On the basis of the above discussion, we have developed two estimating equations for testing the rationality of the farmers of Bangladesh. These are:

(3.2) $\ln(JPRP)_t = a + b\ln(PJPR)_{t-1} + \text{error term}$

(3.3) $\ln(JARA)_t = c + d\ln(PJPR)_{t-1} + \text{error term}$

where,

$JPRP_t$	: the ratio of jute production to aus rice production in period t
$JARA_t$	: the ratio of jute acreage to aus rice acreage in period t
$PJPR_{t-1}$	: the ratio of price of jute to the price of rice in period t-1
a, b, c, d	: the coefficients of regression.

For estimation the technique of ordinary least squares was applied and subsequently was modified by the Corchane-Orcutt iterative process to remove serial correlation among the disturbance terms.14 The results of the regressions are presented in Table 3.1.

TABLE 3.1

PRICE RESPONSIVENESS OF THE FARMERS IN BANGLADESH

(In Terms of Jute and Aus Rice Cultivation, 1947-74)

Eqn. No.	Estimated Coefficients		Durbin-Watson Statistics	R2
3.2	a = -3.10	b = 0.47	1.84	.33
	(-4.18)	(3.08)		
3.3	c = -3.33	d = 0.41	1.88	.38
	(-6.16)	(3.73)		

Figures in the parentheses are respective t-ratios.

The equations reported above have reasonable explanatory power and the coefficients have expected signs with statistically significant 't' ratios. As indicated before, the acreage specification is explained by relative price changes somewhat better than the output specification. The explanatory power of our equations are lower than those of Hussain reported earlier. There may be several reasons for this: First, the period of coverage of these two studies are different. Second, our study incorporates the whole of Bangladesh rather than the nine major jute growing areas selected by Hussain. Finally, Hussain was able to use actual harvest price received by the farmers for the specific crops concerned. On the other hand, our study dealt with the average of all rice prices. Clearly, the farmer is likely to be more responsive to the harvest price of aus rice than that of all rice while making the choice between aus rice and jute. We were unable to make the latter two modifications in our study due to the lack of data.

Based on their responses in the output market, we can stipulate that the farmers in Bangladesh are economically rational and exercise their rationality whenever possible.

III.4.3 Trends in factor and product markets

In this subsection we intend to analyse the factor and product markets in Bangladesh to determine if the need for induced innovation exists in the agricultural sector of the country. As mentioned before, the trends in market prices for these commodities will be regarded as the indicators of their scarcities. The potential scope of this subsection is very large, and, for the sake of brevity, we shall focus on the highlights only. Nevertheless, the analysis has been presented under several headings for the convenience of the readers.

A. Land

Land is one of the most important factors of production in the context of agricultural production anywhere. In Bangladesh, this is more important as its supply is characterized by a high degree of inelasticity. This is more pronounced when viewed against the rapid growth of population in that country. The gravity of the situation is indicated by Table 3.2 which shows the density of population in Bangladesh for different years during 1901-79.[15]

TABLE 3.2

DENSITY OF POPULATION IN BANGLADESH

(In Heads per Square Mile)

Year	1901	1951	1961	1974	1979
Density	534	761	922	1286	1476

Source: Statistical Yearbook of Bangladesh, Various issues.

In a situation like this, it is reasonable to expect that the price of land relative to other factors, especially labour, shall increase over time.

B. Labour

Bangladesh has traditionally been a labour surplus country. With restricted opportunities for employment in the urban sector, the majority of her labour force has been forced to concentrate in the rural sector.16 Table 3.3 presented below shows the magnitude of such pressure faced by the agricultural sector of the country.

TABLE 3.3

AGRICULTURAL LABOUR MARKET IN BANGLADESH

(In Million Man-Years, except the last line)

Year	60-61	64-65	69-70	73-74
Total Agr. Labour	16.46	18.15	20.82	22.41
Total Agr. Emp.	10.86	12.55	14.07	14.50
No. Unemp. in Agr.	5.60	5.58	6.75	7.91
Percentage of Unemp.	34.0%	30.8%	32.4%	35.3%

Source: Ahmed (1972); Ahmed (1978); and First Five Year Plan of Bangladesh.

In a factor market characterized by excess supply all along, there is no reason to expect its price to rise. In fact, the doctrines of pure economics suggest that the price for a surplus factor should be zero. However given that the subsistence needs of the labourers must be satisfied, they have traditionally commanded a positive wage which is assumed to equal its marginal product in the present study.

C. Fertilizer

In addition to land and labour, fertilizer is another important input in agricultural production. In the present study of Bangladesh, fertilizer assumes an additional importance since under the existing set of scientific knowledge agricultural research activities aimed at induced innovation seek to develop fertilizer-responsive seeds in most of the land-scarce countries.

The analysis of the market for fertilizer in Bangladesh is complicated by several factors. Firstly, it has two major sources of supply: domestic production and imports from abroad. Domestic production is controlled by the government and is also sold by the public sector to the farmers at subsidized prices. Consequently, we cannot regard the selling price of fertilizer as its true opportunity cost. The imported fertilizer is also sold by the government to farmers at the same set of subsidized prices. For these commodities, however, it is possible to get the c.i.f. prices paid by the government.17 Both the subsidized and the c.i.f. prices of fertilizer have important bearings on our study of induced technical change in Bangladeshi agriculture. In the empirical work related to the price of fertilizer reported in this study the subsidized price has been used. The reason for this is that these analyses were concerned with the responses of the farmers and for them the subsidized price payable at the farm gate is more relevant. The c.i.f. or true price of fertilizer assumes importance in a different context. Once we recognize that it is the responsibility of the public sector to steer the directions of induced innovation on the basis of actual situations in the factor and product markets, this price should form the proper basis for decision making. Conversely, if the farmers decide to sponsor AREA, the market or the subsidized price should be the pertinent choice, since this price reflects their private cost of acquiring this factor.[18] To cover both types of situations referred to above, we have used both the subsidized and the true price of fertilizer in calculating the relative prices reported in Table 3.4 below.

D. Mechanical power

The term mechanical power has been used by us to represent both tractors and power pumps used in the agricultural sector of Bangladesh.[19] These modern inputs have also become popular to some extent among the farming communities in recent years, as is apparent from Table 3.9 below. The analysis of this market was easier than that of fertilizer as these equipments are not produced domestically. The c.i.f. prices of these items, quoted in the F. A. O. Trade Yearbook reflect the financial cost for employing these mechanical devices in Bangladesh. In our study these prices were adjusted to take fuel cost and depreciation factors into consideration.20 The price of this input relative to those of other relevant inputs are reported in Table 3.4.

E. Analysis of relative prices for inputs

For a study of induced technical change, the relative price data presented in Table 3.4 are highly relevant. Columns 2 to 5 of the Table show that land has become more expensive relative to other inputs in Bangladeshi agriculture. This reflects the scarcity of land in Bangladesh as well as the technical progress made in the fertilizer and mechanical equipment industries. Based on the data in this Table, one can recommend technical changes of a land-saving and other factor-using nature for the agricultural sector of Bangladesh. Column 6 of the Table shows that the price of labour relative to mechanical power is also increasing. This is surprising for a labour surplus country like Bangladesh and may occur because technical progress in the industries producing agricultural equipment abroad has made these available to Bangldeshi farmers at a gradually declining prices. Nevertheless,

TABLE 3.4
TRENDS IN RELATIVE FACTOR PRICES

Year	Price of Land/Labour	Price of Land/Fert. (Subsidized)	Price of Land/Fert. (Actual)	Price of Land/MP	Price of Labour/MP
1950-51	1.42				
1951-52	1.81				
1952-53	1.96				
1953-54	2.36				
1954-55	2.62				
1955-56	4.23				
1956-57	2.80				
1957-58	3.63				
1958-59	3.29				
1959-60	3.62				
1960-61	3.42	2.71	1.36	3.60	1.05
1961-62	3.22	3.01	1.59	3.67	1.14
1962-63	3.85	3.12	1.65	4.46	1.16
1963-64	3.85	3.54	1.88	4.79	1.25
1964-65	3.52	4.68	2.48	4.73	1.34
1965-66	4.44	5.94	3.15	5.18	1.17
1966-67	5.32	6.72	2.84	6.27	1.18
1967-68	4.79	6.62	2.83	6.05	1.26
1968-69	5.36	7.30	3.29	6.69	1.33
1969-70	4.77	7.50	3.28	N.A.	N.A.
1970-71	4.64	N.A.	N.A.	N.A.	N.A.
1971-72	4.66	9.30	5.67	7.34	1.57
1972-73	5.47	7.61	4.74	5.46	1.00
1973-74	3.00	3.61	2.99	N.A.	N.A.

Source: Various issues of Statistical Yearbook of Bangladesh, Bangladesh Agriculture in Statistics, and F.A.O. Production and Trade Yearbooks.

Note : Bose (1968) estimated that Bangladesi farmers work for 259 days in a year. This information was used to convert labour income into annual figure.

: As modern inputs were largely unknown prior to 1960, we do not have adequate data on them.

since the other price ratios reported in the Table show a faster increase than the ratio of the price of labour relative to that of mechanical power, technologies directed towards saving land (bio-chemical) may have greater pay-offs than those directed towards saving labour (mechanical) in that country.

F. Trends in the product market

The analysis made so far in this subsection has demonstrated that the nature of input market in Bangladeshi agriculture is favourable to induced technical change in the sense that some of the inputs are becoming relatively scarcer. To complete the analysis, we intend to examine similar trends in the product market as well. In Bangladesh, a variety of crops are produced in the agricultural sector. However, to incorporate all of them into the study is quite difficult and is also not worthwhile as most of the crops comprise a very small segment of the total agricultural output of the country. For this reason we have selected four crops for study, which are both relatively important compared to other crops and characterized by the availability of long time series data. The importance of these crops is evident from the fact that throughout the entire period of study they accounted for more than ninety per cent of the total cropped area in Bangladesh. These four crops are jute, rice, sugarcane, and tea.

TABLE 3.5
TRENDS IN RELATIVE PRODUCT PRICES

Year	PR/PJ	PR/PSC	PR/PT	PJ/PSC	PJ/PT	PT/PSC
1950-51	0.68	6.46	N.A.	9.50	N.A.	N.A.
1951-52	0.57	7.38	N.A.	12.88	N.A.	N.A.
1952-53	1.37	7.00	5.65	5.13	4.13	1.24
1953-54	0.66	5.13	3.90	7.75	5.89	1.32
1954-55	0.47	4.19	2.36	8.94	5.03	1.78
1955-56	0.73	7.88	3.78	10.78	5.17	2.09
1956-57	0.87	12.02	5.84	13.77	6.69	2.06
1957-58	0.88	8.56	5.17	9.74	5.88	1.66
1958-59	1.06	8.23	4.82	7.77	4.55	1.71
1959-60	0.85	8.88	3.90	10.45	3.52	2.28
1960-61	0.34	8.28	3.87	24.71	11.55	2.14
1961-62	0.68	6.81	4.39	9.95	6.41	1.55
1962-63	0.80	7.03	3.61	8.78	4.51	1.95
1963-64	0.70	6.30	3.23	9.01	4.61	1.95
1964-65	0.53	6.67	3.89	12.59	7.35	1.71
1965-66	0.78	8.55	4.07	10.96	5.22	2.10
1966-67	0.79	11.44	4.49	14.41	5.66	2.55
1967-68	0.83	11.32	5.20	11.03	5.07	2.18
1968-69	1.03	12.33	5.55	13.60	6.13	2.22
1969-70	1.01	10.06	4.67	9.93	4.61	2.15
1970-71	0.84	9.83	4.20	11.72	5.00	2.34
1971-72	0.90	11.67	3.80	12.93	4.21	3.07
1972-73	0.76	10.63	5.82	14.02	7.68	1.83
1973-74	0.97	8.56	7.18	8.80	7.39	1.19
1974-75	1.23	14.82	14.29	12.00	11.62	1.04
1975-76	1.13	9.69	11.42	8.60	10.13	0.85

Source: Various issues of Statisticial Yearbook of Bangladesh and Bangladesh Agriculture in Statistics.

Note : Pi stand for Price of crop 'i'; J: Jute, R: Rice, SC: Sugarcane, and T: Tea.

Table 3.5 presents the relative prices of these crops computed pairwise for the period 1950-78. From a careful study of the Table we find that the relative prices of these crops have fluctuated quite widely over the years and it is very difficult to establish a smooth trend, as was possible for the inputs. This indicates that the nature of final demand conditions prevailing in the agricultural market of Bangladesh does not provide any definite clue as to the direction of induced innovation.

III.4.4 Public sector sponsorship of AREA

It has already been mentioned that in the developing countries it is very difficult on the part of the farmers to organize themselves for collective action. Bangladesh is no exception to this general feature of the developing countries. Politically, the country was under the colonial rule of the United Kingdom as a part of an Indian province until 1947. When the British left, no stable government with democratic representation could be established, and from 1958 onwards, she came under the influence of military governments. The situation after 1971, when Bangladesh became a separate nation, has not changed much from the past. In other words, among the three types of motivation suggested in Section III.2, namely, government with an agricultural base, farmers pressing the government for AREA and the perception of the need for AREA by the government, the first two are absent in the context of Bangladesh. Consequently, the only motivation for investing funds in AREA by the public sector in Bangladesh can come from the voluntary realization by the government that such investments will have high pay-off and are absolutely necessary for the agricultural sector of the country.

III.4.5 Actual investments in AREA in Bangladesh

The actual investments in AREA in Bangladesh was very low both in absolute amounts and as a proportion of the gross domestic product in agriculture. The data presented in Table 3.6 are taken from Evenson and Kislev (1975) which show the amounts of such investments in Pakistan during the year 1965. The data on actual investments in AREA in Bangladesh for other years of the sixties or the early seventies could not be gathered and Evenson and Kislev did not provide separate information for the two components of the then Pakistan, namely, East Pakistan (now, Bangladesh) and West Pakistan. However, from the figures of intended allocation in AREA during the Third Five Year Plan period (1965-70), we find that the share of Bangladesh was approximately one third of the total investments in AREA.21 Since the Pakistan government was becoming increasingly concerned about the existence of economic disparity between its two provinces and was taking definite measures to reduce this disparity over time the share to Bangladesh during the earlier years could not have been more than this. Based on this assumption, we have calculated the share of Bangladesh in investments in AREA in 1965 and reported this in Table 3.6.

TABLE 3.6

ALLOCATION OF FUNDS TO AREA IN PAKISTAN AND BANGLADESH IN 1965

(In Thousands of U.S. Dollars)

	Investment in AREA	Investment as percentage of GDP in agriculture
Pakistan	11,041.00	.23
Bangladesh	3,683.00	.16

Source: Evenson and Kislev (1975); and our estimate.
Note: - Pakistan refers to the pre-1971 political unit.

The Third Five Year Plan target for annual allocation of funds to AREA in Pakistan was U.S.$4,832 thousands per year. From this it appears that the actual investment in 1965 as reported by Evenson and Kislev was not a major deviation from the trend. Compared with the corresponding figures for other countries for the same year, presented in Table 2.2 we find that the emphasis placed on AREA in Bangladesh (or even in Pakistan) was very low. In addition, the Joint Pakistan American Agricultural Research

Review Team found that the Pakistan Agricultural Research Council, which was responsible for financing and co-ordinating agricultural research at the national level had failed to co-ordinate research throughout the country and that the flow of information between public and private research workers and the exchange of information with foreign research institutes could be improved.[22,23]

III.5 External Features of Induced Innovation : A Case Study of Bangladeshi Agriculture

In Section III.3 we have identified two types of evidences of technical change. These are: an increase in productivity and the appearance of new inputs or outputs. Quite often these two factors indicate a close relationship and to save space and repetitions we shall discuss them together in this section in the context of the agricultural sector of Bangladesh. Towards the end of the section an attempt is made to integrate these two factors on the basis of Bangladeshi experience.

Until now the major emphasis of AREA in Bangladesh was directed toward a single crop, rice. The high yielding varieties of rice, which included IRRI-8, IRRI-20, BR-5, were introduced in the mid-sixties. The rate of adoption of these seeds among Bangladeshi farmers is shown in Table 3.7.

TABLE 3.7
RICE CULTIVATION IN BANGLADESH
(LV: Local Varieties, HYV: High Yielding Varities)
(In Millions of Acres and Maunds per Acre)

	Acreage LV	Acreage HYV	Percent in HYV	Yield LV	Yield HYV
BORO RICE					
1967-68	1.38	0.156	10%	17.36	41.07
1968-69	1.66	0.360	18%	17.93	39.46
1969-70	1.60	0.580	27%	17.72	40.35
1970-71	1.57	0.857	35%	17.44	37.71
1971-72	1.39	0.795	36%	15.12	33.07
1972-73	1.35	1.088	45%	14.78	33.52
1973-74	1.14	1.454	56%	14.53	30.15
1974-75	1.14	1.629	59%	14.80	27.22
1975-76	1.25	1.587	56%	14.22	28.01
1976-77	0.90	1.215	57%	13.84	26.75
1977-78	1.25	1.455	54%	16.40	27.82
AMAN RICE					
1969-70	14.81	0.029	0.2%	13.38	34.92
1970-71	13.78	0.200	1.4%	11.68	28.89
1971-72	12.75	0.626	4.7%	11.37	30.30
1972-73	12.74	1.379	9.8%	10.27	19.34
1973-74	12.09	2.043	14.4%	11.26	26.07
1974-75	12.23	1.239	9.2%	10.97	23.53
1975-76	12.86	1.376	9.7%	12.36	23.90
1976-77	13.31	1.046	7.3%	12.29	23.37
1977-78	13.69	0.567	4.0%	13.64	26.93
AUS RICE					
1970-71	7.81	0.080	1.0%	9.62	36.07
1971-72	7.30	0.121	1.6%	8.25	29.02
1972-73	7.08	0.164	2.3%	8.10	27.72
1973-74	7.35	0.329	4.3%	8.96	31.52
1974-75	7.16	0.699	8.9%	8.23	27.07
1975-76	7.58	0.872	10.3%	8.52	26.78
1976-77	7.05	0.901	11.3%	8.44	24.92
1977-78	6.86	0.953	12.2%	8.80	25.34

Source: Statistical Yearbook of Bangladesh, various issues.
Note: Maund is Bangladeshi weight unit (1 Maund = 82.08 lbs).

The most striking feature of Table 3.7 is the fact that the introduction of the high yielding varieties of seeds has largely been concentrated in the boro crop. This crop grows in the winter season and is dependent, to a large extent, on a controlled water supply. The boro crop constitutes a very small proportion of the total rice area under cultivation. The bulk of Bangladeshi rice comes from aus and aman crops which are rainfed varieties and grow under deep water. The development of high yielding seeds for these crops has not been successful thus far. The main reason for this is that instead of concentrating on indigenous research, the public sector in Bangladesh tried to rely on the easier alternative of borrowing technology from abroad. The high yielding varieties in use in Bangladesh owe their origin, either directly or through adaptation, to their parent varieties developed at the International Rice Research Institute (henceforward referred to as IRRI), Los Banos, Philippines. Evidently, the outcome of the researches done by the institute situated in the Philippines has failed to bring about any significant effect on the agricultural sector of Bangladesh. It is clear that in Bangladesh a pressing need exists for carrying out successful research activities oriented towards the environmental conditions and factor supply situations of that country so that it may suit the bulk of the rice crop.

Similarly, little research effort has been directed with a view to develop high yielding varieties of other important cash crops of the country which include jute, sugarcane and tea. The yield per acre of these crops in Bangladesh has been virtually constant or declining over the years. This fact is evident from the yield rate of these crops shown in Table 3.8.

TABLE 3.8

YIELD PER ACRE IN BANGLADESH

(For Selected Crops During 1950-78)

Crop:	Jute	Sugarcane	Tea
1950-51	1,403 lbs.	15 tons	7.9 tons
1955-56	1,304 lbs.	15 tons	8.3 tons
1960-61	1,175 lbs.	14 tons	6.5 tons
1965-66	1,218 lbs.	17 tons	7.7 tons
1972-73	1,176 lbs.	17 tons	5.9 tons
1977-78	1,188 lbs.	17 tons	6.7 tons

Source: Various issues of Statistical Yearbook of Bangladesh and Bangladesh Agriculture in Statistics.

The consequences of not developing improved production technologies for these important cash crops can be quite significant. These crops are the major foreign exchange earners for Bangladesh and thus should be the subject of major research and development programmes. There is another important reason that justifies the application of greater attention to these crops. Since the cultivation of these commodities are relatively more labour-intensive and since the high yielding varieties tend to require more manual labour, the development of high yielding varieties of these cash crops could help reduce unemployment. A recent study by the F.A.O. (1975) indicates that the man-days required for each acre's cultivation of rice and jute are fifty and ninety respectively, when both are grown by the traditional method. Consequently, the observed neglect of AREA in Bangladesh towards these labour-intensive crops leads us to believe that the relative factor supply situation was not considered in framing the agricultural development policies of the country.

As a result of the evidence presented thus far in this subsection, we can observe that one indicator of technical change, the appearance of new outputs in the agricultural sector of Bangladesh, was not in evidence. The other indicator, an increase in the consumption of new inputs in Bangladeshi agriculture (apart from the high yielding seed varietis already discussed) is presented in Table 3.9.

TABLE 3.9

USE OF MODERN INPUTS IN BANGLADESHI AGRICULUTRE

(For Selected Years)

(In Thousands of N. Tons or Horse Power)

Year	1960-61	1973-74	Percentage increase
Fertilizer	22.50	177.43	688%
Tractor/Tiller	42.20	180.00	327%
Power Pump	20.51	530.15	2,468%

Source: Various issues of F.A.O. Production Yearbook and Bangladesh Agriculture in Statistics.

We are now in a position to state some broad conclusions regarding the nature of changes in the agricultural sector of Bangladesh. These are:

(a) The spread of high yielding varieties of rice was mostly concentrated in the boro crop.

(b) Apart from rice there has been little spread of high yielding varieties in other crops.

(c) The expansion of acreage mostly came from the increase in boro cultivation.

(d) There was a great increase in the use of other modern inputs such as fertilizers, tractors, and power pumps.

To reconcile the above statements it is necessary to show the link between the spread of high yielding varieties in boro crop and the simultaneous increase in the application of modern inputs in the agricultural sector of Bangladesh. In this endeavor we were severely handicapped by the lack of precise data. Ideally, one would like to have information on various inputs applied to traditional rice varieties at the beginning and at the end of the period. In addition, one would like to know the corresponding magnitudes of inputs applied to high yielding varieties. Unfortunately, we could gather evidence on the nature of various inputs used in traditional and high yielding varieties of crops only for recent periods. However, this will not be a major problem if we assume that the patterns of input use in the traditional varieties of rice did not change much during the period. This assumption can be supported by studies which have shown that traditional allocation and availability of inputs are optimum for the traditional crop varieties. It has also been found that the marginal product of modern inputs, especially fertilizer, to these crops become negative at a very low-level of absorption.24

We have reported in Table 3.10 below two recent studies on comparative input requirements between traditional and high yielding varieties of rice in Bangladesh. The coefficients quoted in those studies (and hence in our Table) are not in terms of physical inputs but in terms of the man-hours or man-days associated with the operation of each type of input. Since the man-time employed in these inputs are likely to be proportional to the physical application of these inputs, these coefficients can be used to get some information regarding the intensities in which different inputs are employed in traditional and in high yielding seed varieties in Bangladesh.

Based on constant man-time requirements per input in both the varieties, the coefficients of Table 3.10 suggest a higher incidence of modern inputs such as power pumps and fertilizers in the cultivation of high yielding varieties of rice.

In another study, the Kahnert et al. (1970) found that during the period 1966-70 the rates of fertilizer application to traditional and high yielding varieties were 6.27 lbs. per acre and 58.75 lbs. per acre respectively.25 The same study also observed that high yielding varieties are more susceptible to pests and should receive relatively more attention in terms of plant protection.26

TABLE 3.10

LABOUR INPUTS USED ALONG WITH OTHER FACTORS
IN LOCAL AND HIGH YIELDING RICE VARIETIES IN BANGLADESH
(LV: Local Variety; HYV: High Yielding Variety)

TABLE 3.10 A

(In Man-hours per Hectare)

	LV	HYV
Sowing and Transplanting	284	328
Fertilization	49	105
Power Pumps	8	34
Harvesting	235	314
Thrashing	91	168

Source: Ahmed (1976), p.110

TABLE 3.10 B

(In Man-days per Acre)

	LV	HYV
Land Preparation	11.29	20.54
Sowing/Seeding	11.62	28.31
Harvesting/Thrashing	11.52	20.12

Source: Muqtada (1975), p.409

Finally, the following Table taken from F.A.O. (1975) shows a striking difference in the use of modern inputs in traditional and in high yielding varieties of rice.

TABLE 3.11

MONEY INVESTED IN VARIOUS INPUTS

IN RICE PRODUCTION IN BANGLADESH

(In Takas per Acre)27

Crop	Traditional	High Yielding
Fertilizer	Nil	190.00
Plant Protection	Nil	20.00
Water	Nil	300.00

Source: F.A.O. (1975), p. 14, Table 1.

The message implicit in the estimates of F.A.O. and Kahnert et al. as well as in those of Ahmed (1976) and Muqtada is that the major share of modern inputs used in the agricultural sector of Bangladesh has gone to the high yielding varieties of rice. Our own finding reported in Appendix A, that irrigation, which was used as a proxy for package inputs in agriculture, was highly significant with a positive sign in the fertilizer demand equation, also supports the view that all these inputs have been used together.

The upshot of all these arguments is that the use of modern inputs in the agricultural sector of Bangladesh, whatever its magnitude may be, did show up mainly in the cultivation of high yielding varieties of crops, while the techniques in traditional varieties did not benefit from modernization.

Incidentally, it may be mentioned that the sudden drop of excess supply of fertilizers in Bangladesh during the early years of the seventies can be explained by the increase in the area under high yielding varieties during that period.28 Following the main thread of our current argument, the rapid increase in the adoption of high yielding varieties of the boro crop increased the demand for fertilizers correspondingly, which resulted in a reduction in the excess supply of fertilizer in that period.

III.6 Formulation and Testing of Hypothesis

On the basis of the findings stated thus far in this chapter it is possible to formulate a hypothesis regarding the nature of induced adjustment in the agricultural sector of Bangladesh. Since no systematic trend was found in the relative price movements of the agricultural outputs, any test of induced output adjustment in Bangladesh will be inconclusive. Consequently, the test reported here will concentrate on induced input adjustment only.

To recapitulate, the study has so far identified six factors that merit some consideration before the application of any formal test of induced adjustment. These factors are:

(a) Rationality: Both the farmers and the public sector must respond to economic incentives.

(b) Favourable trends in input and/or output markets: This requires that at least some factor or product should gradually become more expensive or cheaper to provide the incentives for inducing the change.

(c) Communication between the farmers and the public sector: This builds pressure on the public sector to sponsor AREA aimed at induced innovation in agriculture.

(d) Growth of agricultural research under public sector sponsorship: This is the vital part of induced technical change through which new inputs and technical know-hows are generated.

(e) Appearance of new inputs and/or outputs: This indicates that a new technology has been introduced and accepted by the farming community.

(f) Rise in agricultural productivity per acre and/or per man: This is the ultimate objective of the entire process of AREA and supplies a measure of success for it.

In our analysis, we have observed that considering the agricultural sector of Bangladesh as a whole, three of the above factors, namely, 'c', 'd', and 'f' are almost non-existent. Growth of modern inputs, however impressive in percentage terms, is still negligible compared to the vast area of nearly twenty nine million acres put under cultivation every year. About rationality, even if the farmers are rational, we could find no evidence of rationality on the part of the public sector. The farmers, on the other hand, are unable to exercise their rationality as far as initiating research is concerned, since they are constrained by the prevailing institutional arrangements. Under these circumstances, the nature of technical change in the agricultural sector of Bangladesh, if any, can hardly be endogeneous in character.

It rather seems more plausible from the analysis that the public sector in Bangladesh sponsored AREA aimed at the winter rice crop in particular, and supplied new inputs intended to improve its cultivation. In that case the application of induced input adjustment test is likely to show better results when applied separately to the winter rice crop only. However, since such disaggregated data are not available, it was not possible to carry out such a test. On the other hand, it follows that the application of any test of induced adjustment on the agricultural sector of Bangladesh taken altogether, which does not meet the requirements specified above, should result in poor response in terms of statistical qualities as was the case with similar tests in France, Egypt, and Syria reported in Chapter II. Future work in this section will test this hypothesis against the empirical evidence for Bangladeshi agriculture.

The test has been designed by following the work of Hayami and Ruttan described in Chapter II. It was observed in that chapter that the test is not free from criticisms and that more sophisticated tests for induced innovation have been developed by Binswanger. However, given the lack of adequate data, we have no other alternative than to fall back on the Hayami-Ruttan test. It may be mentioned that the sophistication of the data required for his many-factor test prevented Binswanger from applying it even to Japan, a country in possession of an enviable stock of statistical information regarding herself. Briefly speaking, in the Hayami-Ruttan test relative changes in the consumption of various agricultural inputs, taken two at a time, are regressed on the relative prices of the factors. As such, the regression equations employed by us were:

(3.4) $\ln(QFER/QLAND)_t = a + b\ln(PFER/PLAND)_t + c\ln(PMP/PLAND)_t + d\ln(PLAB/PLAND)_t$ + error term

(3.5) $\ln(QMP/QLAB)_t = a + b\ln(PMP/PLAB)_t + c\ln(PFER/PLAB)_t + d\ln(PLAND/PLAB)_t$ + error term

(3.6) $\ln(QLAND/QLAB)_t = a + b\ln(PLAND/PLAB)_t + c\ln(PMP/PLAB)_t + d\ln(PFER/PLAB)_t$ + error term

where,

MP : mechanical power (defined earlier)

Qi_t : quantity of factor i consumed in period t

Pi_t : price of factor i in period t

a, b, c, d : regression coefficients (they assume different values in different equations).

The data for the analysis were collected from various issues of the Production and Trade Yearbooks, published by the F.A.O. as well as from various publications of the government of Bangladesh. The period of study was restricted to a span of fourteen years from 1960 to 1974. The choice of this particular time period was guided by two factors:

(a) In Bangladesh, the use of modern inputs was not very significant in the decade of the fifties. This suggested that 1960-61 should be a good choice as the starting year.

(b) The data for some of the variables were not available beyond 1973-74.

The results of the regressions are presented in Table 3.12 below.

TABLE 3.12

RESULTS OF INDUCED INPUT ADJUSTMENT TEST FOR BANGLADESH, 1960-74.

Eqn. No.	Regression Coefficients	Durbin Watson Statistics	R2
3.4	a = 1.38 (0.91) b = 1.16 (4.43) c = -2.15 (-11.83) d = -1.97 (-4.23)	2.08	.80
3.5	a = 2.17 (1.77) b = -3.13 (-21.78) c = 2.01 (5.07) d = 1.66 (4.44)	2.37	.20
3.6	a = .061 (2.43) b = .004 (1.10) c = -.005 (-1.76) d = .005 (0.78)	2.88	.62

Figures in the parentheses are respective t-ratios.

From Table 3.12, it is evident that the changes in the factor proportions in the agricultural sector of Bangladesh did not take place in response to changes in their relative prices. Equations (3.4) and (3.6) indicate quite high degree of explanatory power in terms of the coefficient of determination. However, in these cases the perverse responses of factor proportions to the changes in relative prices raise doubts as to their validity. In equation (3.5) the direct explanatory variable has the right sign and is statistically significant. The explanatory power of the equation, on the other hand, is low.

The analysis presented earlier in this chapter suggests that the prices of the agricultural inputs in Bangladesh bear some relation to their scarcity value. In such a situation, the observed non-response or perverse response of factor proportions to changes in relative factor prices rejects the claim of endogeniety of technical change in the agricultural sector of Bangladesh. At the same time, these findings also support the hypothesis set to test in this section.

III.7 The Public Sector and AREA in Bangladesh

We have seen that in the devloping countries the role of the public sector in generating technological breakthrough in agriculture is important. The findings reported in Section III.4 indicate that the public sector in

Bangladesh did not offer the country a sound programme of AREA. There the study focused on the inadequacy of funds invested in AREA. In this section we intend to show not only that the funds invested in AREA were inadequate, but that they were misdirected as well.

Throughout the entire period under study, it had been the policy of the governments in Bangladesh to offer fertilizer and other mechanical equipment to the farmers at highly subsidized prices. From our analysis of the demand for fertilizer in Bangladesh, reported in Appendix A, it is found that the decision to subsidize fertilizer was a welcome step. The appendix observes that despite a huge potential demand for fertilizers the entire amount available each year was not consumed by the farmers.29 This suggests the use of subsidies to induce farmers into increasing their application of fertilizer. At the same time it is also necessary to provide complementary inputs and ensure proper water supply so that the farmers can efficiently use this fertilizer. The fact that, despite the subsidy and a huge potential demand for it, the fertilizer market in Bangladesh is characterized by excess supply suggests that the public sector failed to provide an adequate supply of complementary inputs.

It may be mentioned that any attempt to popularize fertilizer in a labour surplus economy is also consistent with attempts to reduce unemployment. The use of fertilizer is not associated with any labour displacing effect, which is a characteristic of any form of mechanical power. On the contrary, there is evidence that the use of fertilizer may be labour using. Apart from the fact that its application requires more labour there are certain cultural practices associated with the use of fertilizer, such as weed control that increase employment. These features become more pronounced when fertilizer is used with high yielding varieties of seeds as they call for more attention in terms of human care. It has been estimated by Muqtada that the application of seed and fertilizer under the high yielding varieties programme in Bangladesh has increased labour employment by thirty to fifty per cent.

At the same time the policy of the public sector to provide tractors and tillers at subsidized prices and also the policy of importing these (and thus using up scarce foreign exchange) reveals a major contradiction when viewed in the context of relative factor endowments of Bangladesh. It is evident from Table 3.3 that there is a considerable degree of unemployment among the agricultural labour force of the country. Since tractors, or similar forms of mechanical power, tend to replace human labour; the use of tractors and tillers in the agricultural sectors of labour abundant countries has created a great deal of controversy.30 In the case of Bangladesh, one study by Ahmed (1976) has shown that the use of tractor and tiller techniques reduce labour utilization by forty per cent in the case of boro cultivation and by twenty seven per cent in the case of cultivation of the high yielding varieties. The author also observed that the decline would have been much greater but for the relatively higher labour inputs for fertilization and weeding for which no adjustments were made. Another interesting finding of the study was that the use of tractor/tiller technology was not associated with any increase in land productivity.31 It may be mentioned that in our regression equation (3.5), reported in the last section, we also observed that the relationship between the consumption of mechanical power and the wage rate is negative which indicates the labour displacing effects of mechanical power in Bangladesh. Interestingly, during the early phase of public sector intervention in agriculture, Japan also spent huge amount of money on mechanization. But she soon realized the mistake and turned attention towards the bio-chemical technology and achieved a high rate of agricultural growth.32

Our earlier analysis has indicated that there is a shortage of complementary inputs to seeds and fertilizers in Bangladesh. In addition, the country has not developed a sound indigeneous research system in agriculture. The absence of sufficient financial resources is, no doubt, a major reason for the sluggish performance in these areas. Under these circumstances, the opportunity cost of using up a portion of the financial and foreign exchange allocations in agriculture through the imports of tractors and tillers may be very high relative to the benefits foregone. It is high time that the government should put an end to these types of expenditures and lay more emphasis on the provision of complementary inputs as well as in building up an efficient system of agricultural research for the country. The remainder of the thesis is devoted towards building a model to serve as a guide to fulfilling the latter objective.

III.8 Summary of the Chapter

This chapter has been quite lengthy and warrants a brief summary. In Section III.2 we have listed some forces that help the process of induced innovation in agriculture and named them the "internal features" of induced innovation. This was followed by a section which identified some direct evidences of technical change in agriculture. To maintain symmetry with the earlier analysis, we called these the "external features" of induced innovation in agriculture. The importance of these features are quite high in any empirical analysis of the subject. First, they can be used to interprete the results emanating from any formal test of induced adjustment in agriculture. Second, a careful study of these features may help us formulate some hypotheses regarding the expected results from tests of induced adjustment in agriculture. The latter approach has been used in the present chapter. Sections III.4 and III.5 have examined both the internal and external features of induced technical change for the agricultural sector of Bangladesh. The behaviour of most of these features were found not conducive to induced innovation. On this basis, we hypothesized in Section III.6 that any test of induced adjustment in Bangladeshi agriculture will yield poor or negative results. The hypothesis was tested against empirical data from Bangladesh and was found acceptable. Finally, Section III.7 presented a critical appraisal of the role of the public sector in terms of providing some of the related services.

The purpose of the entire study, as mentioned before, is to build a guiding model for allocating funds to AREA. As a step towards it, some of the characteristics of agricultural technologies and of AREA are discussed, inter alia, in the next chapter while the model itself is presented in Chapter V.

FOOTNOTES TO CHAPTER III

1. The expression "agricultural research and extension activities appear many times throughout the study. To save space and to ease the process of reading we have decided to refer to it in its abbreviated form: AREA.

2. In this and in the subsequent chapters, any reference to Hayami and Ruttan will represent their entire work related to induced innovation in agriculture which appears in Hayami and Ruttan (1970, 1971 and 1973). In the case of any particular reference the specific work involved will be cited.

3. See Hayami and Ruttan (1971), p.57.

4. The idea is similar to that of Uphoff and Ilchman (1972) who suggested that the public sector should provide leadership in organizing the farmers to press for research. See Chapter II of our study.

5. A gain in productivity can be obtained from sources other than induced innovation such as discovery of fertile land, direct import of some technology which accidentally suits the country (even though this may be inferior compared to the gains possible through an appeal to induced innovation).

6. The reason for this is that the agricultural sector is dependent on the public sector in many ways.

7. Equation (3.1) is the form in which this test has been applied in the literature. An equation similar to this can be derived from the profit maximizing behaviour of a farmer when he allocates a fixed amount of land, LF, to two crops X and Y. If W is the agricultural wage rate, the supply functions for X and Y can be written as:

$$(3.7) \quad \ln X = a(0) + a(1)\ln(PX/PY) + a(2)\ln W + a(3)\ln LF$$

$$(3.8) \quad \ln Y = b(0) + b(1)\ln(PX/PY) + b(2)\ln W + b(3)\ln LF$$

Subtracting equation (3.8) from equation (3.7) and assuming $a(2) = b(2)$ and $a(3) = b(3)$, we get

$$(3.9) \quad \ln(X/Y) = e + f\ln(PX/PY)$$

which is similar in form to equation (3.1) of the main text. For a discussion on deriving supply functions under the assumption of profit maximization see Chapter VI.

8. A detailed analysis of various aspects of farmers' response can be found in Chapter VI.

9. See Tables 6.1 to 6.3, in particular.

10. A discussion of traditional agriculture, especially in the context of Bangladesh, is available in Ullah (1974).

11. Other things remaining the same, an encouragement to produce any particular crop can come through the provision of AREA toward that crop. Other measures of directive control, especially licensing of cropwise land allocation failed in the context of Bangladesh. For example, the Bengal Jute Regulation Act of 1940 empowered the government to issue licenses for jute cultivation with a view to regulate its acreage. This act was put into practice in the then East Pakistan (now, Bangladesh) upto 1960. However, the Report of the Jute Enquiry Commission (1960) observed that during 1947 to 1960, the actual area allocated to jute exceeded that fixed by the licenses in nine years implying that the law was violated while it was quite low compared to the licensed maximum in the remaining four years indicating that the law was not necessary for those years.

12. The cropping seasons for various rice varieties and jute in Bangladesh are:

Crop	Growing Period
Aman rice	April to August
Aus rice	February to April
Boro rice	November to February
Jute	March to May

The overlapping between jute and aman and aus crops are obvious from above.

13. Since most of raw jute of the undivided India was grown in East Bengal (now, Bangladesh), these findings implicitly describe the behaviours of the farmers of Bangladesh.

4. A comprehensive treatment of various econometric terms used in this chapter can be found in Johnston (1972).

15. It may be mentioned that barring the city states of Hong Kong and Singapore, Bangladesh is the most densely populated country of the world. Even in the neighbouring state of India the density of population per square mile is approximately 520.

16. Although no formal estimate of urban unemployment in Bangladesh is available, a recent study by Farashuddin (1979) indicates that it is quite high.

17. This term, common in international transactions, stands for cost, insurance and freight.

18. The farmer will have to assume that the subsidy will continue in future years at the same rate.

19. These were combined by assuming an average of 50 Horse Power for tractors and 15 Horse Power for power pumps and tillers. These Horse Power figures were obtained from various issues of the Bangladesh Agriculture in Statistics.

20. The adjustment coefficients were derived from the study of Bose and Clark (1969).

21. These figures have been calculated from the data reported in Kahnert et al. (1970), p.227.

22. Private research, especially in agriculture, is virtually absent in Pakistan and Bangladesh. It appears that the committee report was referring to the research done at the universities as private research.

23. See the Report of the Joint Pakistan American Agricultural Research Review Team, Islamabad, April 6, 1968.

24. Hayami and Ruttan (1971) have cited a specific example of this in the context of Bangladeshi agriculture. See ibid, p.84.

25. See Kahnert et al. (1970), Table 45, p.396.

26. See ibid, p.203.

27. Taka is the unit of Bangladeshi currency. Currently one U.S. dollar equals approximately 15.06 Takas.

28. This is reported in Table A.1 in Appendix A.

29. See Table A2.2 in the Appendix A.

30. For an excellent survey of the controversy, see Butler, Banerji and Yudelman (1971).

31. See Ahmed (1976), pp. 361-63.

32. A brief discussion of this aspect of the Japanese agricultural development is provided in Chapter II (Subsection II.3.2).

CHAPTER IV

NATURE OF AGRICULTURAL RESEARCH AND EXTENSION ACTIVITIES

IV.1 Introduction

In Chapter II we mentioned that technological change in the agricultural sector has some special characteristics which reduce the efficiency of the market mechanism in ensuring socially proper allocation of resources to AREA. The main purpose of the present chapter is to substantiate this claim from both empirical and theoretical points of view. Section IV.2 draws evidence from Japan, atypical of the countries with heavy investments in various forms of research and development, to indicate the actual existence of differences in motivation between the private and the public sector towards agricultural and manufacturing research. Section IV.3 distinguishes between various forms of technological change in agriculture in order to explain the apathy of the private sector towards AREA. A schematic model for AREA is developed in Section IV.4. Section IV.5 uses the arguments made in the preceding sections to justify the need for public sector intervention in AREA while the next section presents some estimates of returns from AREA in various countries across the globe. Finally, Section IV.7 summarizes the findings of the chapter.

IV.2 Public and Private Sectors in Research and Development

Historically, most of the indigeneous research activities in industry emanated from private sector initiatives while the bulk of agricultural research operations were sponsored by the public sector. To keep the analysis brief, we refrain from making a detailed survey of this pattern around the world and cite an example from Japan, a country which has undertaken high levels of investment in research and development in both agriculture and industry. The data is presented for one year only, 1972, on the assumption that what happened in 1972 is representative of similar events for other years as well.[1] It has been estimated that about eighty percent of the research expenditures in the industrial sector of Japan in 1972 were spent by the private sector against a mere six per cent by the public sector. The remaining fourteen per cent were contributed by the universities. On the other hand, the corresponding figures for expenditures in agricultural research in that year were: private sector, four per cent; public sector, sixty one per cent; and the universities, thirty five per cent.[2]

The nature of research done in the universities and that sponsored by the public sector are quite similar in the sense that both are usually motivated by non-profit considerations and the outcome is made available to everyone as a free or public good.3 In addition, most of the expenditures for university research are financed, directly or indirectly, by the public sector. As such, the research done in the above institutions can be termed as non-private or public sector research. Under this interpretation, the share of the public sector in total expenditure on agricultural research in Japan in 1972 rises to ninety six per cent while only four per cent originates in the private sector. For the industrial sector the corresponding figures are twenty per cent and eighty per cent respectively.

The observed tendency of the private sector to support industrial research heavily while neglecting the agricultural sector supports the view that research and subsequent extension work in the latter sector must have some special characteristics that distinguish it from the former. In the following discussions we shall look into the peculiar features associated with AREA that discourages the private sector and, hence, calls for public sector intervention.

Since the endproduct of the research system is technical change, it is necessary to identify various components of technical change in agriculture, before any meaningful analysis can be done. These components are discussed in the next section.

IV.3 Classification of Technologies in Agriculture

The relationships between research activities and technical change in agriculture can be expressed in a better way if we can identify various components of such technical change. One of the pioneering studies seeking to classify technical changes in agriculture is due to Heady (1949). He believed that such changes are of two types: mechanical and biological. Mechanical progress in agriculture has little yield increasing effect and is aimed basically at saving the labour cost of production, i.e., it is labour saving in nature.4 On the other hand, biological progress increases the yield per unit of land and can be termed as land saving. Sen (1959) employed the concepts of "labouresque" and "landesque" capital while Kaneda (1969) divided agricultural technologies into "mechanical engineering technology" and "bio-chemical technology" respectively. These classifications are similar to those of Heady, and need no further discussion.

In their book, Hayami and Ruttan (1971) have explicitly recognized three types of technologies (hence, technological changes) in agriculture. These are: mechanical, biological, and chemical. In addition, they have mentioned a fourth type: cultural practices. Improvements in mechanical technologies include innovations like harvesters, tractors, and power pumps for irrigation.

For the most part of their analysis, Hayami and Ruttan have found it convenient to treat biological and chemical technologies jointly. Developments in the latter technologies are identified by the appearence of hybrid seeds and other improved plant materials, new breeds of cattle and various varieties of fertilizers and insecticides. They, however, pointed out that the distinction between these two broad types technologies might be overdrawn for the purpose of exposition. According to them, not all mechanical innovations are motivated by the incentives to save labour. They observed that in certain instances Japanese mechanical technologies had some yield increasing impact while the bio-chemical technologies in the U.S. showed some evidences of saving labour. Nevertheless, they concluded that historical evidence strongly supports the commonly held view that mechanical innovations are basically labour saving with little effect on yields, whereas advances in bio-chemical technologies show a land saving and yield increasing effect.

In his recent study of Argentine experiences in agricultural development, De Janvry (op. cit.) found it convenient to identify four broad types of agricultural technology. These are: mechanical, which includes tractor, harvestor, and windmill; biological, which includes hybrid seeds and cattle breeds; chemical, which refers to fertilizers, insecticides, and pesticides; and finally, agronomic, which covers cultural practices and management techniques such as crop rotation, permanent pastures, forage reserves, and fertility tests. These technologies can be characterized in terms of their impacts on the marginal rates of technical substitution between capital, labour and management and the levels of yield from land.

De Janvry followed the suggestions of Seckler (1970) and made a distinction between "on line" management and "staff" management. The former deals with the actual directions of farm activities, while the latter refers to decision making as a choice of activities and of techniques such as investment decisions, financial and fiscal administration, and commercial activities. The net effects of each type of innovation on the employment of various factors is described below:

Mechanical innovations raise the productivity of labour mainly through permitting increases in the availability of land per worker. By reducing labour costs, they will also reduce on-line management requirements. Staff-management requirements, however, are likely to go up as capital intensity of the firms will increase.

Biological innovations are fairly neutral with respect to labour and management requirements. They are slightly capital using and moderately yield increasing when used outside of complete packages of techniques.

Chemical innovations tend to increase the yield. Basically they are land saving in nature and permit the substitution of capital and labour for land. However, they are capital and labour deepening in the sense that they require both more on-line and staff-management per unit of land.

Finally, agronomic innovations, according to De Janvry, are labour and on-line management using and land saving. They are also characterized by a strong yield increasing impact.

It is hoped that our study will benefit from this brief analysis of classification of agricultural technologies on several counts. First, a knowledge of the special features of different types of agricultural technologies, especially the attributes of the public good nature associated with them, will be useful in explaining the unwillingness of the private sector to sponsor the research aimed at developing these technologies. Second, an insight can be obtained on the employment generating potential (of labour in particular) embedded in different types of technologies. Finally, as mentioned before, an acquaintance with various technological possibilities in agriculture will be of substantial help in comprehending the relationship between AREA and the concomitant technological changes in agriculture. The next section is a step forward in this direction as it presents a detailed discussion of the main elements of AREA in the context of the developing countries.

IV.4 The Process of Propagating AREA

In this section we shall present two flow charts describing an agricultural research system which will be useful in understanding the link between public sector research and technical change in agriculture. These will also help us explain the costs involved in the transfer of technologies from another country. These charts have been developed from those presented by Solo and Rogers (1972) with some modifications.

The first flow chart depicted in Figure 4.1 traces out the general features of an agricultural research system. It is characterized by several "stop actions" at discrete points in time to separate different stages or steps. In the figure we have identified four stages and nine major flows in the process of propagating AREA.

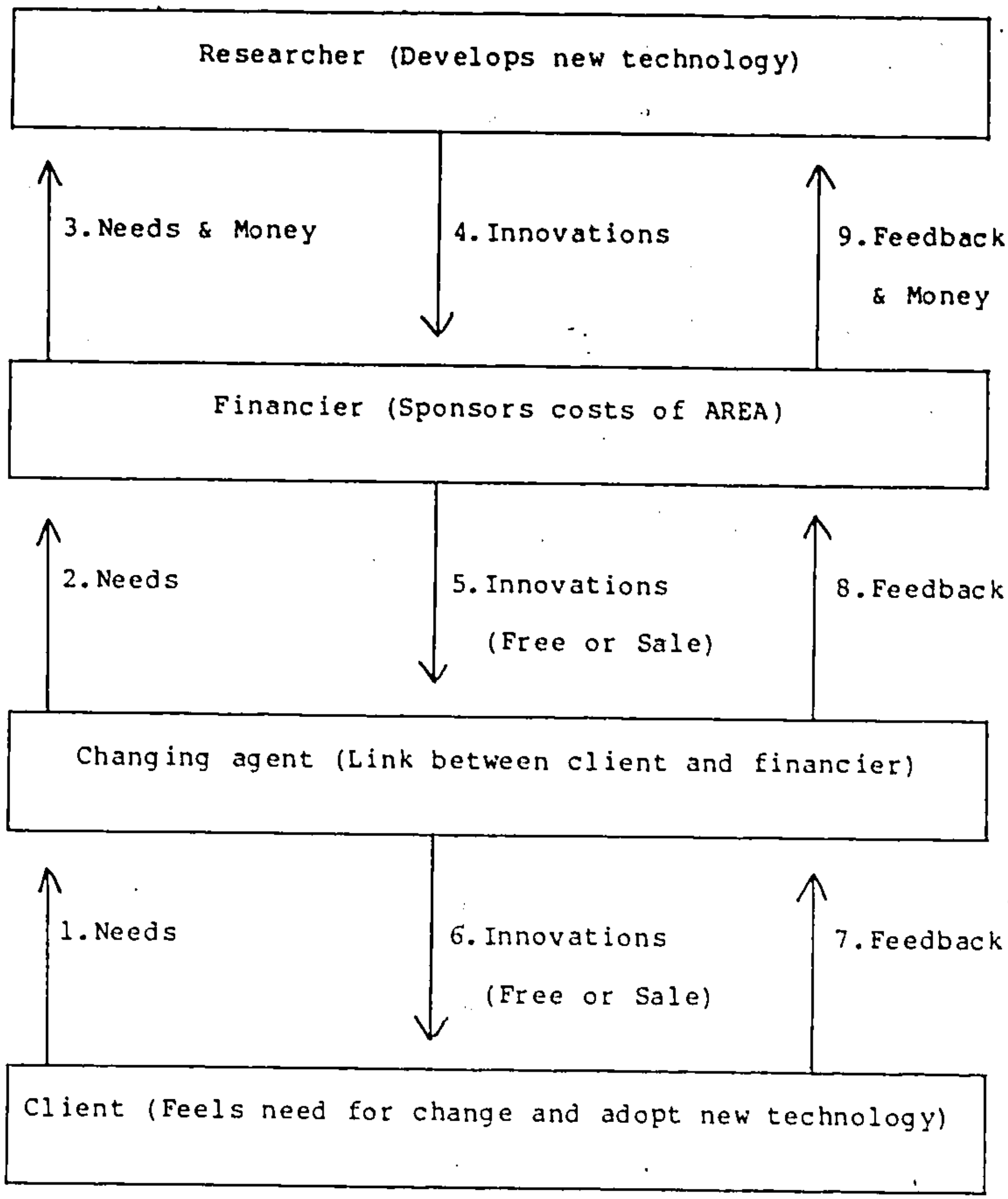

Figure 4.1 A Flow Chart Describing AREA

The stages shown in the figure are:

(1) Clients : They are the people at the grass root level who recognize the need for research to bring about a change in technology. This leads to the beginning of the research process. At the end the clients adopt the innovations coming out of research.

(2) Changing agents : They perform the important function of translating the clients' needs to the financiers willing to undertake the costs of research. They are also responsible for diffusing the innovations among its ultimate users. In other words, they are the people entrusted with the extension component of AREA.5

(3) Financiers : They perceive the usefulness of bearing the expenditures of research either to make a profit or to increase the level of social welfare. Depending on their motive, they also sell the research outcome with a mark-up or at a nominal price.

(4) Researchers : They create and/or develop research results which are then utilized (also by them) to generate innovations.

The communication flows numbered in the figure are explained below:

Number 1. Flow of the client needs (for information) to the changing agents.

Number 2. After initial interpretation and classification, these needs are transferred to the financiers for approval.

Number 3. The needs are transferred to the researchers with necessary funds.

Number 4. Researchers attempt to provide needed information for clients either from accumulated knowledge or via research and they hand these over to the financier.

Number 5. Depending on the motive, the financier either sells the innovations to the changing agents or supply these at a nominal price.

Number 6. Changing agents distill and interprete this new information (innovation) for clients.

Number 7. Feedback from clients to changing agents on the adequacy of the new information in fulfilling their needs.

Number 8. This flow is essentially same as Number 2.

Number 9. This flow is essentially same as Number 3.

It should be mentioned that the above is a very simplified model of the process of AREA. In reality, the number of flows may be much larger. In addition, some of the stages may overlap in the sense that the same agency may perform different functions. It is possible to introduce such modifications into the system. The chart can then be used to build a comprehensive model for investing funds in AREA. This, however, would require considerable amount of primary data not available to us. Consequently, we have built an alternative model with the same objective in mind which is presented in the next chapter.

The other flow chart presented below takes a different view of the research system which may be more relevant for the developing countries. It is represented in Figure 4.2.

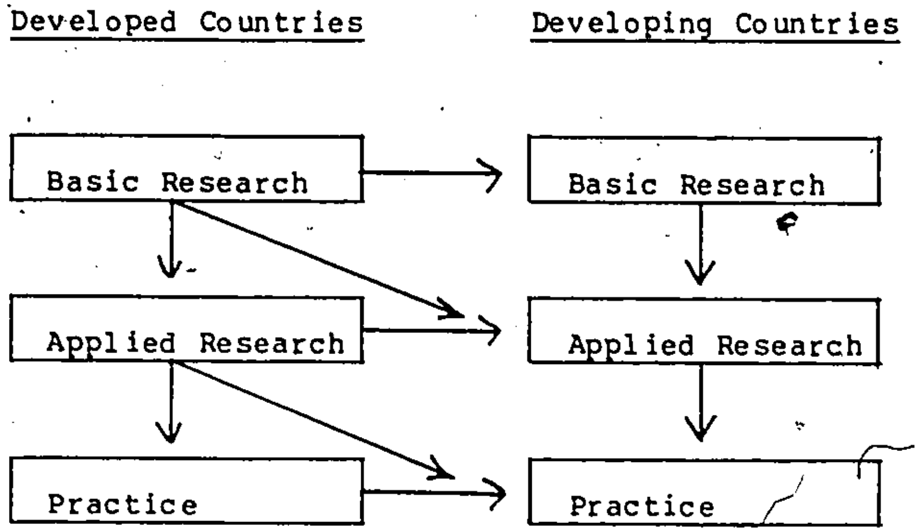

Figure 4.2 The Research System in a Developing Country

Figure 4.2 is characterized by three types of flows. These are horizontal, vertical, and diagonal flows. Horizontal flows describe cross-national communication of research outputs. Various analyses of the communication behaviour of scientists suggest that these information flows face little resistance apart from those of a cultural and spatial nature.6 Vertical flows stand for the conversion of the outcome of research into technological innovations and operating practice. The main elements of this flow have been described in the research utilization diagram of Figure 4.1. The resistance encountered in this flow is much greater than the horizontal flows as it is concerned with various heterogeneous groups of people. Diagonal flows represent cross-national flow from research tō the next stage in line. They encounter both types of resistance faced by the horizontal and vertical flows and, as such, are least powerful in terms of effectiveness.

Considering Bangladesh as a typical example of the developing countries, we find that the common trend in such countries is to by-pass the vertical flows, hence the entire process described in Figure 4.1 along with all of its merits. These countries mainly rely on diagonal flows in the sense that they tend to borrow or copy the outcomes of research of the developed countries. Both the theoretical arguments of Ahmad (1966) and the empirical findings of the last chapter suggest that this choice of the easy route to technological progress may be ineffective.

IV.5 Sponsoring Research in Agriculture

In the preceding sections we have examined the possible avenues along which agricultural technologies can develop and described how this development is related to AREA. Indigeneous research has been found to be a key element in bringing about progress in the state of technology. It is possible to identify three sources which can finance the costs of AREA. These sources are: (a) owners of the firms that will apply the improved technology, (b) private intermediary firms which may sell these technologies for profit, and (c) the public sector which might be interested in improving the technology for the economic development of the country concerned or may be forced to do so by various pressure groups described in Chapter III. Historical evidences, cited at the beginning of the current chapter, show that in the case of manufacturing sectors a significant proportion of research originated in their own firms. The major industrial concerns of the western world are known to set aside a portion of their annual allocations for research and development activities. The reason for taking such active interest in research is, of course, the familiar profit motive. Through successful research operations, they hope to lower their cost of production or supply new improved products into the market.

Unfortunately, profit incentives, which prove to be the dominant force behind industrial research are not sufficient to generate a similar level of research in the agricultural sector. The primary reason for this is the fact that the amount of resources involved in the agricultural operations of individual owners is much lower compared to the manufacturing sector. Under this situation the farmer or even a group of farmers hardly find the expected returns attractive enough to justify massive investments in research. It is interesting to note, however, that those technological innovations that could be achieved without too much expenditure in research, did occur through the initiative of the farm entrepreneurs as soon as their needs were felt. A classic example of this is the nature of agrarian changes in eighteenth century England. Faced with a fall in land productivity, the farmers quickly adopted improved cultural practices (agronomic innovation, by our definition), such as new methods of tillage and drainage and rotation of crops, which led to an increase in productivity.7

The agricultural sector fails to benefit substantially from the second source of research sponsorship, namely, private firms supplying technologies, as well. Such firms are essentially suppliers of new and improved inputs to the users. The reason for their lack of interest in agricultural production activities is that in most of the cases it becomes very difficult to establish exclusive rights to their inventions.8 Agricultural inputs which can be marketed with little difficulty are tractors, power pumps and the like. For this reason most of the private sector research aimed at the agricultural sector has been channeled toward mechanical technology. The use of such equipment may be consonant with the economic environments of a relatively labour scarce country, but the attempts to push similar research or its outcome into a labour surplus economy is likely to introduce distortions in the optimal choice of factors.9 Another input that has received some attention from private firms is chemical fertilizers. However, the incentives of private firms to innovate and sell improved varieties of fertilizers have been reduced by the fact that from the farmer's point of view the use of better fertilizer by itself does not raise the productivity level. The farmer's desire to buy such fertilizers depends, to a great extent, on the availability of complementary inputs, such as high yielding seed varieties, which will not be developed by a market-oriented, profit-maximizing firm for the reasons described earlier in the text.

The end result is that investment in seed research, which has been one of the key elements in bringing about sharp increases in the agricultural productivity of the developed countries did not materialize through the initiatives of the private sector. This naturally places more emphasis on the last source for sponsoring researh activities in agriculture, the public sector. Obviously, the public sector may be motivated by a broader motive of over all economic progress. In this new framework induced innovation can be viewed to take place not only in response fo changes in market prices but also in direct response to changes in resource endowments without the intermediating influence of market prices.

IV.6 Empirical Works on Measuring Gains from AREA

IV.6.1 Introduction

Throughout the entire discussion we have repeatedly claimed that investment in AREA is a crucial step towards the attainment of technological change in agriculture. In this section we intend to establish the link between agricultural research and growth in the agricultural sector from an empirical viewpoint by analysing the experiences of various countries and agencies engaged in agricultural research.

Economists have attempted to measure the benefits from agricultural research in various ways. These may be broadly classified into four categories:

(a) Public relations approach,

(b) Index number approach,

(c) Internal rate of return approach, and

(d) Production function approach.

A detailed discussion of these approaches is presented below in four separate subsections numbered IV.6.2 to IV.6.5.

IV.6.2 Public relations approach :

This approach incorporates those works where what research has accomplished and/or what it is expected to accomplish in future is described in general terms. Most of the government documents on AREA fall in this category. The works of Chandler (1975) and Anderson (1975) seeking to explain the tremendous success in research achieved by two international agencies of long repute, namely, the IRRI and CIMMYT (International Maize and Wheat Improvement Center, Mexico) are also of this nature.

The study by Evenson and Kislev (1969) on research and changes in productivity in sugarcane cultivation around the world can also be said to follow the public relations approach. Certain findings of their work are highly interesting and implicative for our present study. They observed that Indonesia was one of the pioneers in initiating research leading to improvements in sugarcane. This was followed by similar research in other areas such as Hawaii, Louisiana and Florida in the U.S.A., Puerto Rico, India, Australia, and the British West Indies. As a result, all these countries experienced a steady gain in the yield from sugarcane production.10 On the other hand, Cuba was the only major sugarcane producing country which failed to develop a substantial research capability and, hence, experienced a continuous decline in yields. The policy of the Cuban government was to use the research experience of Florida, which evidently failed. Another interesting finding of their study is that Indonesia experienced a decline in yields since 1942. The reason for this is the outbreak of the Second World War and the Indonesian Revolution of 1945-49. Following these disturbances, Indonesian sugarcane cultivation was disrupted and her agricultural research system was destroyed as a symbol of colonial exploitation. After this, Indonesia did not build up an efficient research base again and continued to face yield declines.11 This clearly supports our basic contention that continued indigenous research is vitally essential for achieving and maintaining a high level of agricultural productivity.

IV.6.3 Index number approach :

The pioneering work in the more quantitative methods of evaluating the returns to investment in AREA can be attributed to Schultz (1953) and Griliches (1958,1964). The former is responsible for developing the index number approach while the latter should be credited for the initiation of the internal rate of return and the production function approaches. Schultz calculated the value of inputs saved in U.S. agriculture resulting from improved, more efficient production techniques. Using a conservative estimate he found that output per unit of input was thirty two per cent higher in 1950 than in 1910. The total saving in the value of inputs in 1950 was estimated to be $9,600 millions which was substantially greater than even his largest estimate of $7,000 million spent on AREA from 1910 to 1950.

Peterson (1971) applied Schultz's technique to the comparable data extended upto 1967. He also corrected the over-statements in the costs of AREA assumed by Schultz. His findings are reported in Table 4.1.

TABLE 4.1

CONTRIBUTIONS OF THE AREA IN THE U.S., 1910-67

(In Millions of U.S. Dollars)

Period	Total Research Bill	Value of Inputs Saved in		
		1950	1967	1950-67
1910-50(a)	3,757	10,110		
1910-67	9,457		25,904	
1950-67	5,700			337,000

a: Presents Shultz's figures corrected by Peterson
Source: Peterson (1971)

IV.6.4 Internal rate of return approach :

Most of the empirical work on agricultural research and productivity has followed this approach.12 The internal rate of return may be defined as the rate of interest that makes the accumulated present value of the flow of costs equal to the discounted present value of the flow of returns at any given point in time. Mathematically, it is calculated by solving the following equation for 'r' through the method of iteration:

$$(4.1) \qquad \sum_{t=0}^{n} \{R(t)-C(t)\}/(1+r)^{t} = 0$$

where,

r : internal rate of return

R(t) : gains from research in period t

C(t) : costs of research in period t

n : length of the programme.

The gains from research have been calculated in two alternative ways: namely, values of the input saved and total changes in consumer and producer surpluses on account of the shifts in productivity. The findings of the major studies in various countries of the world are presented in a summarized form in Table 4.2.

It is clear from Table 4.2 that the internal rates of return from investing in AREA had been very high in almost all the cases. Compared with the plausible values of rates of interest in these countries, investing funds in AREA appear to be a very lucrative proposition. The only exception to this generalization is the fact that the

TABLE 4.2

INTERNAL RATES OF RETURN FROM AREA

Study	Year	Country	Product	Period	I.R.R.
Griliches	(58)	U.S.A.	Hybrid Corn	1940-55	35%-40%
			Hyb.Sorghum	1940-57	20%
Tang	(63)	Japan	Agr. Sector	1880-38	35%
Peterson	(67)	U.S.A.	Poultry	1915-60	21%-25%
Evenson	(68)	U.S.A.	Agr. Sector	1949-59	47%
Barletta	(70)	Mexico	Wheat	1943-63	90%
				1943-63	35%
			Crops	1943-63	45%-93%
Schmitz & Seckler	(71)	U.S.A.	Tomato harvester	1958-69	37%-46% (a)
					16%-28% (b)
Ayer and Schuh	(72)	Brazil	Cotton	1924-67	77%-110%
Hines	(72)	Peru	Maize	1954-67	35%-40% (c)
					50%-55% (d)
Hayami & Akino	(77)	Japan	Rice	1915-50	25%-27% (e)
				1930-61	73%-75% (f)
Hertford et al.	(77)	Colombia	Rice	1957-72	60%-82%
			Wheat	1953-73	11%-12%
			Soybean	1960-71	79%-96%
			Cotton	1953-72	Nil
Peterson et al.	(77)	U.S.A.	Aggregate	1937-67	34%-51%
Kahlon et al.	(77)	India	Aggregate	1960-73	63%

a: Assuming no compensation to displaced workers; b: assuming such compensation equal to 50% of their earning; c: for maize only; d: including maize research and complete package; e: before Assigned Experiment System; f: after Assigned Expt. System.

internal rate of return from research in cotton in Colombia turned out to be zero. The authors of that particular study attribute this result to the tendency of cotton researchers in Colombia to try to import and apply varieties developed in the U.S.A. This adds additional support to our claim that local research is the best possible way to bring about an increase in agricultural productivity.

IV.6.5 Production function approach :

In this approach, the authors attempted to fit an agricultural production function taking annual expenditures in AREA as a variable input. Griliches (1964) estimated an aggregate agricultural production function for the U.S.A. and found that between 1949 and 1959, the marginal product of expenditures in AREA was second only to fertilizers and was higher than the marginal products of machinery, labour and other factors of production. He concluded by observing that "A new variable, public investment in research and extension is introduced and found to be both 'significant' and important as a source of aggregate output growth".13

Evenson and Kislev (1973) evaluated the performance of the IRRI and CIMMYT in sixty four wheat growing countries and forty nine maize growing countries to determine the effectiveness of agricultural research and observed that "...there is a strong and persistent relationship between agricultural research and biological productivity yield in wheat and maize...indicate a high pay-off to research work".14 They used research publications as a proxy for research expenditures and found that direct contribution per publication in wheat ranged from U.S.$14,308 to U.S.$64,634 while that in maize varied from U.S.$7,575 to U.S.$74,094. In addition, they also calculated the contributions emanating from accelerating borrowing and other sources. The most important finding of their research is that there is no substitute for indigenous research and that without this, simple borrowing of technologies can be of little usefulness.

Finally, in a study of the Indian system of agricultural research Evenson and Jha (1973) found that the major determinant of productivity change in Indian agriculture was her agricultural research system. They also found that the social rate of return from investments in agricultural research was far in excess of those realized in other development activities. The marginal contribution from the investment of Rupees 1,000 in research was the generation of an income stream ranging from Rupees 7,960 to Rupees 10,650 in cases of state research and Rupees 800 to Rupees 3,100 in cases of regional research outside the state.15,16

IV.7 Summary of the Chapter

The arguments presented in this chapter support the view that although the returns from AREA have been very high in different countries of the world, the farmers do not have any motivation to initiate such research on their own. The main reason for this is that the gains to individual farmers from agricultural research are not likely to be sufficient to cover the costs. Similarly, private firms are also less enthusiastic to enter into agricultural research operations as it will be difficult for them to establish exclusive rights to the products of such research since these products possess the characteristics of a public good. This suggests that the public sector should come forward to sponsor AREA as a whole to realize benefits for the entire economy. Once this point is accepted, the next question is how should AREA funds be allocated among various agricultural operations. The subsequent chapters of the thesis seek to find a general solution to the problem and apply the knowledge gained thereby to the agricultural sector of Bangladesh.

FOOTNOTES TO CHAPTER IV

1. It may be mentioned that although levels of research and development investment may change cyclically, the composition should be fairly stable for a mature economy like Japan.

2. See Hayami and Yamada (1968).

3. The theory of public finance defines a public good as one for which it is difficult to establish property rights and the consumption of which does not reduce the consumption of others. Technical knowledge or hybrid seeds produced through research clearly possess these features. For a detailed discussion of public goods see Buchanan (1968).

4. Although not explicitly mentioned, these articles seem to take the literal meaning of the term " 'i'th factor saving" as some change that reduces the employment of factor 'i'. Our study also uses the same interpretation for the term "factor saving".

5. It is possible, of course, that the changing agents for the upward and downward flows constitute different sets of people.

6. A corroboration to this statement can be found in Solo and Rogers (1972).

7. For a discussion of changes in English agricultural and cultural practices, see Timmer (1969), pp. 375-95.

8. Even if property rights could be established by making genetic changes in seed varieties that prevent seed duplication, such rights may not be allowed as it might lead to the creation of monopoly power among the firms concerned.

9. A pertinent example of this type of distortion has been provided by Sanders and Ruttan (1978), in the context of technological change in the agricultural sector of Brazil.

10. For a further breakdown of these yield changes see Evenson and Kislev (1975), pp. 46-47.

11. These historical facts are described and explained in Barnes (1967), Geertz (1966), and Rosenfield (1955).

12. Two closely related concepts, namely, the external rate of return and the benefit-cost ratio from research have also been reported by some authors. In this study we have quoted the internal rate of return whose value is quite low compared to the external rate of return.

13. See Griliches (1964), p. 972.

14. See Evenson and Kislev (1973), p. 1324.

15. Rupee is the Indian unit of currency, approximately equal to U.S.$0.12.

16. Regional research is defined as the research done in other states with similar geo-climatic features.

CHAPTER V

A COMPLETE ALLOCATION MODEL FOR AREA

V.1 Introduction

From the discussions presented to this point two general conclusions stand out:

(a) Returns from investments in AREA are very high, and

(b) Failure to recognize the importance of AREA may have contributed to the poor performance of the agricultural sector of Bangladesh in terms of gains in productivity.

It is encouraging to note that even though the amounts of funds allocated to AREA in Bangladesh was very low in the past, recently the government has paid more attention to the problem.1 Nevertheless, both the government itself as well as a study group from the International Bank for Reconstruction and Development (popularly known as the World Bank) have observed that the co-ordination among various research agencies in Bangladesh is missing and that there is a marked absence of priority considerations among the different programmes of agricultural research.2

The findings reported above underscore the importance of establishing proper priorities among various research and extension programmes. The fact that returns from investments in such operations are highly attractve does not preclude the consideration of allocation of such resources from among its alternatives. Technical progress in agriculture, as we have seen in Chapter IV, can proceed along different paths, each having different impacts on agricultural productivity, on the employment of factors, and on the distribution of income among different groups of people. Consequently, a planner with funds to invest in AREA must analyse the several questions before taking any decision. These are:

(a) Whether the objective of AREA should be to develop new inputs or to improve the quality of the outputs, or both?

(b) Depending upon the answer to the first question, which of the inputs and/or outputs shall be included in the programme for research and extension?

(c) How much money shall be spent in each of the inputs and/or outputs selected for AREA?

(d) What are the possible distributional effects resulting from improved production techniques, if the programme proves to be successful?

It should be pointed out that the implications of the above questions become more pronounced for a country faced with a restricted supply of both financial and human resources for AREA. Obviously, this is a major problem for most of the developing countries. In view of these considerations we propose to present, in this chapter, a formal model for allocating funds for AREA keeping the above issues in the forefront. The chapter is divided into six sections. In Section V.2, we discuss the first question mentioned above and show that for the agricultural sector of a land-scarce country, in particular, the distinction between input and output to be developed through AREA is irrelevant. Section V.3 turns to a brief review of studies by others which are related to our model. Some important theoretical concepts relevant to the model are discussed in Section V.4, while the model itself is presented in the next section. The chapter concludes with a summary which appears in Section V.6.

V.2 Input versus Output Choice

The purpose of this section is to resolve one of the questions posed in the introduction of the present chapter, namely whether to develop inputs or outputs through AREA. The arguments developed here show that for technological developments in the agricultural sector the choice is generally made concurrently.

We have already observed that technical progress in any sector or industry can proceed in two directions. There may be improvements in the quality of the product in response to changes in consumers' demands. Alternatively, it is also possible to have improvements in the quality of the inputs used in production process. Empirical support for both types of technical progress have been provided in the literature cited in Chapter II. Once the existence of the twin directions of technical change are recognized the problem of allocating funds for investment in AREA becomes relatively more complex as more variables with diverse characteristics have to be considered in the decision making process.

The problem, however, is not so serious for the agricultural sector. Apart from a few general innovations, like tractors, most of the input innovations in agriculture are also uniquely linked with some particular output. This relationship is most pronounced for seed-based technologies where the development of any seed variety automatically takes the output of a particular crop for granted. For land-scarce countries, advances in the bio-chemical technology have a distinct advantage over similar progress in the mechanical technology as the former alleviate the constraint on productivity imposed by the lack of land.

Under competitive conditions, the scarcity of any factor relative to another is reflected in the trends in the ratio of prices between them: the ratio should increase if the price of the scarce factor is in the numerator and vice versa. The same conclusion holds good in an imperfect economy provided the degrees of monopoly are same in the relevant markets. Consequently, the simple test of analysing the trends in factor price ratios can be used to determine the nature of relative factor scarcity in any country satisfying either of the above conditions. This information can then be utilized to find out the most appropriate input saving directions for AREA.

For Bangladesh, in particular, the trends in relative factor prices reported in Table 3.4 in Chapter III clearly suggest that over time land is becoming relatively scarce. This calls for an advancement in the bio-chemical technology to suit the prevailing relative factor endowment. Historically, the advances in this technology have been manifested through innovations in high yielding varieties of seeds. On account of the arguments placed above, the question of selecting between inputs and outputs as the object of innovation loses its significance for the agricultural sector of Bangladesh. Like most of the countries striving towards advances in the bio-chemical technology, these choices will be made simultaneously in that country if she attempts to develop the appropriate technology.

As the present study is mainly concerned with the analysis of technological innovations in the agricultural sector of Bangladesh, the model developed here is based on the premises that appropriate choice of input and output are made simultaneously. This, however, does not restrict the overall applicability of the model. Scarcity of cultivable land is a major problem in many countries of the world. Even the land abundant countries in many cases find it advantageous to develop high yielding seed varieties.3 In addition, certain other types of technological innovations in agriculture, like harvesting machines, which are basically labour saving, are also developed with some specific crop in mind. The analysis of investment decisions for AREA for these situations can also be carried out through the use of the model developed in this chapter.4

V.3 A Review of Related Studies

Even though the model developed here is the first complete model built to determine the optimal allocation of funds to AREA and to analyse its consequences some previous studies have analysed the ex post effects of technical change in the agricultural sector.5 The ex post analytical framework differs substantially from the ex ante allocation model presented here. Nevertheless, the ex post works still constitute the basis of our model and the development of its benefit functions were to some extent influenced by them. A review of the major elements of these studies and their relevance to our model is the subject matter of the present section.

Griliches (1958) first applied the concept of economic surplus to the estimation of the benefits from investment in AREA. He also estimated the shares of producers and consumers in the total benefit. Griliches' study was concerned with the effects of investment in research and extension in hybrid corn varieties in the U.S.A. He assumed linear supply and demand curves and utilized a secondary source estimate for the elasticity of demand parameter. No attempt was made to get an estimate of the elasticity parameter for the supply function. Instead he used two extreme values for it, zero and infinity, which specify vertical and horizontal supply curves respectively. Griliches found several estimates of the "shift parameter" for the supply function and used the lowest one among them to be on the conservative side.6 With the help of these parameters and the concepts described in Section V.4 below, he was able to derive mathematical expressions to measure different types of benefits emanating from a technical change in agriculture and to estimate them empirically with actual data.

Peterson (1967), Barletta (1970), Ayer and Schuh (op. cit.), and Hayami and Akino (1977) have used models based on Griliches' framework to analyse the effects of technical change in various agricultural crops or activities. Their formulii are more complicated because they introduced positively sloped supply curves. In addition, they also modified the linear functions used by Griliches, by introducing non-linear demand and supply curves.

The general features of all of the works mentioned above are as follows: Starting from an equilibrium market condition for a commodity which has benefitted from investments in AREA, the hypothetical supply curve which would have existed in the absence of the research induced shifts is estimated. The different areas bounded by the two supply curves, the demand curve and horizontal lines through the actual and hypothetical equilibrium points are then measured to calculate various expressions for benefit.

One limitation common to all of the studies, except that of Ayer and Schuh, is that their authors have either expanded various exponential expressions for benefits by mathmematical formulii and dropped the terms containing higher exponential powers (of the shift parameter) or have resorted to other simplifying approximations to measure the relevant areas. Such an approach obviously results in an imprecise estimate which may not be serious in an analysis involving a single commodity. But where several commodities are involved (as in the present study), the degree of imprecision may be different for different crops, depending on the curvature of the respective demand and supply functions which will affect the results of a comparative study more seriously. In addition, these studies are restricted to closed economies and do not consider the effects of supply change, for any crop, by a country which operates within the framework of an international market. Due to the factors described above and due to the fact that these are concerned with ex post analysis, the models described above are not capable of dealing with the problem of ex ante analysis of AREA involving several crops where all or some of these are traded in world markets.

Ramalho de Castro (1974) applied the ex post framework described above to an ex ante analysis of the effects of a postulated technical change in agriculture. He observed that there is a tremendous potential for achieving benefits from technical change in the production of most of the prominent crops across Brazil. He was interested in finding out what would happen if there was a gain in productivity in each of these crops and to rank these crops in terms of gains for the purpose of allocating funds for agricultural research. He specified linear demand and supply curves with finite slopes and postulated a hypothetical supply curve by assuming an arbitrary ten per cent shift in all supply curves due to postulated technical progress. On the basis of the above specifications, he built a model to calculate the gains accruing to consumers and producers and left the task of allocating research funds among these crops open to the planner.

The idea implicit in the work of Ramalho de Castro is of great importance. He has demonstrated that traditional models for analysing the effects of investments in AREA can be modified to get an ex ante model. However, his model failed to take several important factors into consideration.

First, he has used linear supply and demand curves (without any theoretical or empirical support for such specification) but did not allow for the fact that the measurements of elasticities vary over the range of such curves. He has also used the concepts of arc and point elasticities interchangably in developing his model paying little attention to the discrepancy that exist between these two measures.

Second, he has recognized that some of the crops considered are export crops for Brazil, but he did not present any formal model to deal with these crops. In particular, he did not include coffee into the analysis because "...the relative importance of Brazil in world markets complicate the analysis and caused us to drop it from consideration."7

Third, another serious shortcoming of the model of Ramalho de Castro is that it has failed to incorporate the costs of research and extension activities into it. As a result, his model has little usefulness to a planner seeking to maximize returns from a given amount of investible resources.

In view of the above considerations, we believe that there is a great need for building a complete model for determining the priorities in the allocation of funds for AREA. The model presented in Section V.5 has been specifically developed keeping these objectives in the forefront. It has been cast in a framework of constant elasticity of demand and supply curves since our empirical work with the data of Bangladesh, reported in Chapter VI below, indicates that the non-linear constant elasticity specification for such functions either perform better than or compare favourably with the linear specifications of supply and demand relations. This is not a restrictive assumption and the entire model can easily be modified to incorporate linear functions. The surplus has been computed with exact integrals, so that the only approximation is the specification of the functional forms in place of true relations. Unfortunately, this problem is common in any form of econometric work which seeks to generalize from observed phenomena. We also allow for the possibility that the crop under study may be traded in the world market and focus on both the cases where such trade may either affect the world price level (implying that the country is a major seller or buyer of the commodity) or may not do so (implying that the country is relatively small). Another important feature of the model is that it takes the cost aspects of AREA into explicit consideration. The incorporation of costs turn it into a formal optimizing model, where allocation decisions are made according to marginal principles. Finally, it should be mentioned that in order to retain its practical usefulness as an operative model, it has been formulated in such a way that all the data needed for it are quantifiable.

V.4 The Concept of Surplus

In this section we intend to present a brief review of the concept of an economic surplus which plays an important role in our model, specially in the development of its benefits functions. Since its inception, numerous debates have arisen among economists over the theoretical validity of the concept. However, there is still no consensus among them at present on either its validity or its usefulness in economic analysis. The present model is developed in the tradition of those of its predecessors, cited in the last section, which have used the concept in its present form without getting into the details of the theoretical controversy.

The concept of economic surplus can be analysed better in terms of its two major components, namely, consumers surplus and producers surplus.

A. Consumers surplus

The notion of consumers surplus was introduced by Dupuit (1844) over a century ago. It was developed and brought into the current economic literature by Marshall (1920), Hicks (1940) and Mishan (1976).8 The basic idea of the concept is to measure the difference between the amount a consumer is actually paying for a commodity and the maximum amount he is willing to pay for it. This is illustrated with the help of the following figure.

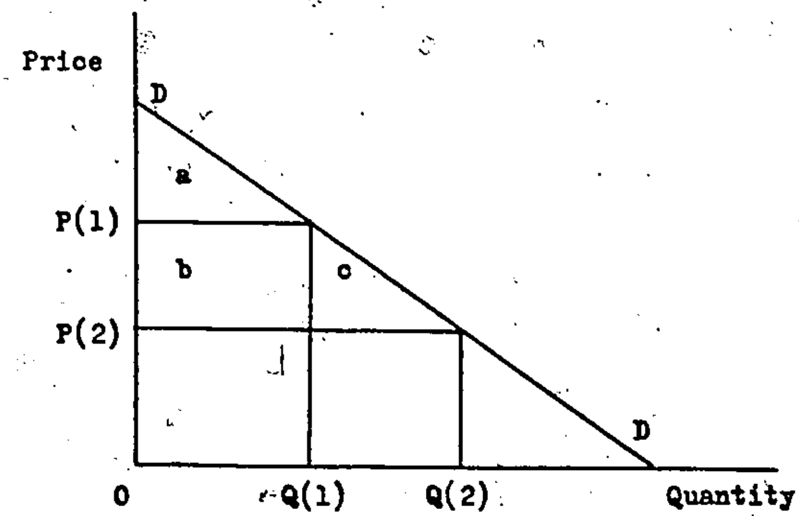

Figure 5.1 The Consumers Surplus

In Figure 5.1, DD represents a usual market demand curve, showing the maximum prices a consumer would be willing to pay for successive, additional units of a commodity.9 If he were forced to pay such maximum prices up to the point where he had purchased, say Q(1) units, he would have made a total expenditure equal in value to the area under the demand curve, DD, and to the left of Q(1) which is equivalent to the area denoted by a+c+b. If, on the other hand, he were to purchase the Q(1) units on the market at a single average price of P(1) units, he would save a value equal to the area under the demand curve above the price line P(1) which equal the area 'a'. This saving is technically referred to as "consumers surplus". Extending the concept further, a fall in the prices from P(1) to P(2) will bring about an additional consumers surplus of the magnitude 'b+c' to the consumer. In other words, this area represents the change in consumers surplus due to the reduction in price from P(1) to P(2).

B. Producers surplus

The concept of producers surplus is analogous to that of consumers surplus. Stated simply, this represents the difference between what is actually received from the sale of a good and the minimum amount required to induce a seller to part with it. The concept is illustrated through Figure 5.2.

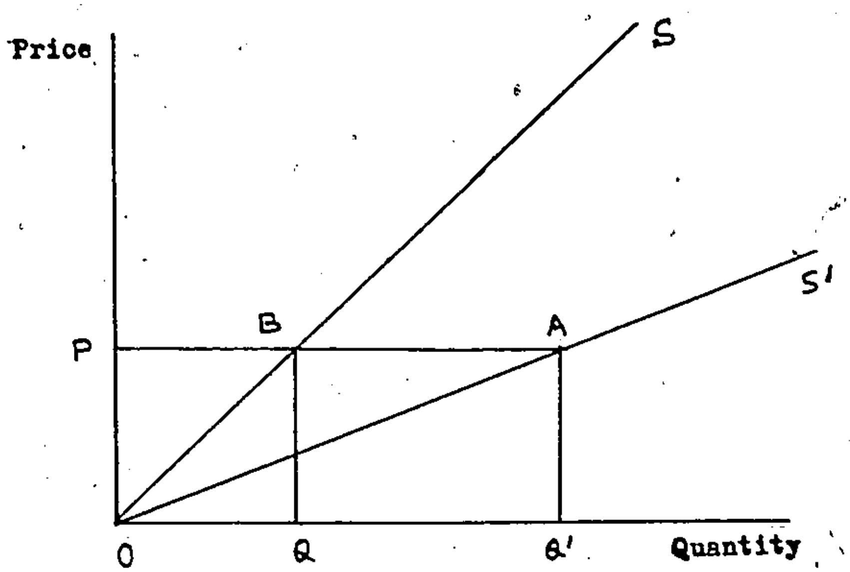

Figure 5.2 The Producers Surplus

The formal analysis of producers surplus is similar to that of consumers surplus and, as such, we describe it briefly here. In Figure 5.2, S is the original short run supply curve for any commodity.[10,11] The producers surplus at any price P is then measured by the area OPB. Since our study requires a measure of change in the surplus, we shall, from now on, focus on the changes in the surplus resulting from technical change in the production function. If such a change shifts the supply curve to the right to S', the change in producers surplus is given by the area OAB.

The concepts of consumers and producers surpluses reviewed above play an important role in the development of the benefit functions: an essential part of the allocation model presented here. Apart from this review, this chapter has demonstrated the relevance of an output oriented model in agriculture and examined previous studies related to our model. The stage is now set for the formal development of the model which is presented in the next section.

V.5 The Model

V.5.1 Introduction

In this section we intend to present the basic theoretical model which will be used to analyse the effects of investments in AREA to establish priorities among various crops for the allocation of such investment funds. The model is made up of three basic components. In the first part the levels of potential benefits from postulated technical changes are expressed as functions of the supply shift parameter. The second part develops the cost functions for AREA and expresses them as functions of the same shift parameter. The interactions between the cost and the benefit functions are examined in the final part of the model to determine the optimum levels of investment in each crop.

V.5.2 The benefit functions

The benefits expected from the increased production and exchange of a crop will be influenced by the context in which the exchange takes place. Within the general framework of a perfectly competitive market, three special cases are considered in the present study. These are:

Case 1 : Purely domestic market.

Case 2 : World market in which the share of the country is relatively large.

Case 3 : World market in which the share of the country is relatively small.

Case 1 refers to the crops that are produced and consumed domestically. These crops are neither imported from abroad to supplement local production nor exported outside the country to get rid of the excess production. The domestic equilibrium prices for such crops are determined through local market conditions and are not influenced by the world price levels.

Case 2 refers to the crops which are traded in the world market and for which the share of the country concerned either as a supplier or a demander is large enough to influence the levels of world prices. To serve our specific needs, we have focused our attention on the supply side only. If needed, a similar model can be developed by emphasizing the influence of the country's demand in the world market. Since the crops are traded in the world market, it is assumed that the domestic price for such crops are also influenced by the respective levels of world prices.

Case 3 is also concerned with the crops which are traded abroad. However, in this case, the share of the country concerned is assumed to be very low. As such, she cannot influence the levels of world prices, however, due to the interaction, such prices are assumed to determine domestic prices.

Case 1. <u>Crops traded in the domestic market</u>

As mentioned before the benefits from postulated technological changes will be measured in terms of demand and supply diagrams. Figure 5.3 below describes such curves for any particular crop i.

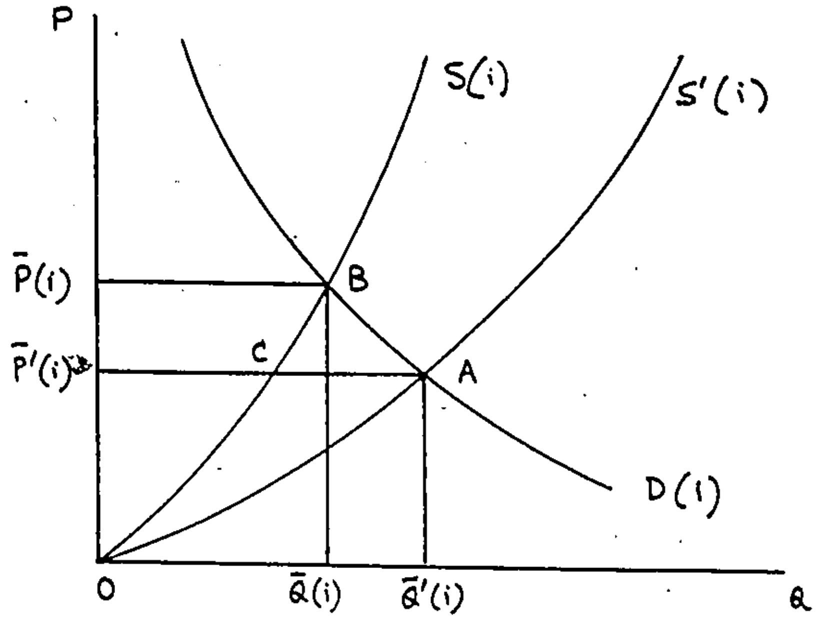

Figure 5.3 <u>Effects of Supply Shift; Case 1</u>

where,

D(i) : the demand curve for crop i

S(i) : the initial supply curve for crop i

S'(i) : the new (hypothetical) supply curve following a technical change in the production of crop i, and is obtained by shifting the initial supply curve to the right by h(i) per cent[12]

$\bar{P}$(i) : the initial equilibrium price for crop i

$\bar{P}'$(i) : the new (hypothetical) equilibrium price for crop i, that will exist if the supply curve actually shifts

$\bar{Q}$(i) : the initial equilibrium quantity for crop i

$\bar{Q}'$(i) : the hypothetical equilibrium quantity for crop i corresponding to price $\bar{P}'$(i).

By utilizing the concepts developed in Section V.3 of the present chapter, we can identify following changes in various measures of benefits emanating from the shift in the supply function.

(5.1) Change in consumers surplus= area ABC+area $B\bar{P}(i)\bar{P}'(i)C$
$= \text{area } B\bar{P}(i)\bar{P}'(i)A$

(5.2) Change in producers surplus= area ACO-area $B\bar{P}(i)\bar{P}'(i)C$

(5.3) Change in total surplus = (5.1) + (5.2) = area OAB

For the actual measurement of the areas specified above, it is necessary to stipulate the functional forms of the demand and supply relationships. As already mentioned, the results of the empirical work suggest the use of constant elasticity demand and supply functions for the analysis.

The demand function

We specify a two variable demand function of the following type:

(5.4) $QD(i) = H(i)\{P(i)\}^{-d(i)}$

where,

QD(i) : the quantity of crop i demanded

P(i) : the price of crop i

d(i) : the price elasiticity of demand for crop i (expressed in absolute term)

H(i) : the parameter representing the influence of other factors on the demand for crop i.

The supply function

Like the demand function, we specify a two variable supply function given by:

(5.5) $QS(i) = G(i)\{P(i)\}^{s(i)}$

where,

QS(i) : the quantity of crop i supplied.

s(i) : the absolute value of the price elasiticity of supply for crop i.

G(i) : the parameter representing the influence of other factors on the supply of crop i.

If the supply curve shifts to the right by h(i) per cent, following a technical change in the production of crop i, the new supply curve is given by:

(5.6) $QS'(i) = (1 + h(i))G(i)\{P(i)\}^{s(i)}$

It should be mentioned that in the above equation h(i) has been measured, not in percentage terms, but in such a way that a 1% shift will read .01. This practice will be followed throughout the analysis unless mentioned otherwise.

The market clearing condition in each of the cases before and after technical change is given by:

(5.7) $QD(i) = QS(i) = \bar{Q}(i)$, say

(5.8) $QD(i) = QS'(i) = \bar{Q}'(i)$, say

Derivation of mathematical expressions for the areas

The formula for evaluating definite integrals has been utilized to compute the areas under the various curves binding the areas to be measured.13 The process of measurement and the results are described below:

(5.9) area $B\bar{P}(i)\bar{P}'(i)A$

$$= \int_{\bar{P}'(i)}^{\bar{P}(i)} QD(i)\,dP(i)$$

Substituting from equation (5.4),

$$= \int_{\bar{P}'(i)}^{\bar{P}(i)} H(i)\{P(i)\}^{-d(i)}\,dP(i)$$

$$= \{H(i)\{\bar{P}(i)\}^{1-d(i)} - H(i)\{\bar{P}'(i)\}^{1-d(i)}\}/\{1-d(i)\}$$

Substituting from equations (5.4) and (5.7),

$$= \{\bar{Q}(i)\bar{P}(i) - H(i)\{\bar{P}'(i)\}^{1-d(i)}\}/\{1 - d(i)\}$$

(5.10) area $B\bar{P}(i)\bar{P}'(i)C$

$$= \int_{\bar{P}'(i)}^{\bar{P}(i)} QS(i)\,dP(i)$$

Substituting from equation (5.5)

$$= \int_{\bar{P}'(i)}^{\bar{P}(i)} G(i)\{P(i)\}^{s(i)}\,dP(i)$$

$$= \{G(i)\{\bar{P}(i)\}^{1+s(i)} - (G(i)\{\bar{P}'(i)\}^{1+s(i)}\}/\{1+s(i)\}$$

Substituting from equations (5.5) and (5.7)

$$= \{\bar{Q}(i)\bar{P}(i) - G(i)\{\bar{P}'(i)\}^{1+s(i)})\}/\{1 + s(i)\}$$

(5.11) area ACO

$$= \int_{0}^{\bar{P}'(i)} (1 + h(i))QS(i)\,dP(i) - \int_{0}^{\bar{P}'(i)} QS(i)\,dP(i)$$

$$= \int_{0}^{\bar{P}(i)} h(i)QS(i)\,dP(i)$$

Substituting from equation (5.5)

$$= \{h(i)G(i)\{\tilde{P}'(i)\}^{1+s(i)}\}/\{1 + s(i)\}$$

To evaluate the above expressions in terms of known parameters; the initial equilibrium values and the supply shift parameter, h(i), we need to express the new price (P'(i)) in terms of these values which is done below:

From the market equilibrium conditions in the situation prior to the occurence of technical change, we get

(5.7) $QS(i) = QD(i)$

Substituting from equations (5.4) and (5.5)

(5.7a) $G(i)\{P(i)\}^{s(i)} = H(i)\{P(i)\}^{-d(i)}$

(5.12) $P(i) = \{H(i)/G(i)\}^{1/(s(i)+d(i))}$

Similarly, by analysing the market equilibrium condition in the post-technical change situation, we get

(5.13) $P'(i) = \{H(i)/G(i)(1 + h(i))\}^{1/(s(i)+d(i))}$

Substituting from equation (5.12)

$$= \{P(i)(1 + h(i)\}^{-1/(s(i)+d(i))}$$

Now with the help of the relationship described in equation (5.13) all the areas involved in the measurement of various benefits can be calculated in terms of h(i) and known parameters of the demand and supply functions.

<u>Expressing the change in total surplus as a function of h(i)</u>

The relationship between the change in total surplus, which shall be referred to as "annual benefits" from now onwards, and the shift parameter h(i) is developed here. It has already been mentioned that this is one of the important relationships needed to compute the optimum values of h(i).

Let the annual benefit from technical change in crop i be represented by the symbol AB(i). We then have

(5.14) $AB(i)$ = area ACO+ area $B\overline{P(i)}\,\overline{P'}(i)A$ - area $B\overline{P}(i)\overline{P'}(i)C$

Substituting from equations (5.9) to (5.11)

$$= \frac{h(i)G(i)(\overline{P}'(i))^{1+s(i)}}{1+s(i)} + \frac{1}{1-d(i)}(Q(i)\overline{P}(i) - H(i)(\overline{P}'(i))^{1-d(i)})$$

$$- \frac{1}{1+s(i)}(Q(i)\overline{P}(i) - G(i)(\overline{P'}(i))^{1+s(i)})$$

$$= \frac{h(i)G(i)(\overline{P'}(i))^{1+s(i)}}{1+s(i)} + \frac{Q(i)\overline{P}(i)}{1-d(i)} - \frac{H(i)(\overline{P'}(i))^{1-d(i)}}{1-d(i)}$$

$$- \frac{Q(i)\overline{P}(i)}{1+s(i)} + \frac{G(i)(\overline{P'}(i))^{1+s(i)}}{1+s(i)}$$

$$= Q(i)\overline{P}(i)\left(\frac{1}{1-d(i)} - \frac{1}{1+s(i)} \right) + G(i)(\overline{P'(i)})^{1+s(i)}(1 + h(i))$$

$$- \frac{H(i)(\overline{P'}(i))^{1-d(i)}}{1-d(i)}$$

Substituting from equation (5.13)

$$= \frac{G(i)(\overline{P(i)})^{1+s(i)}}{1+s(i)}(1 + h(i))^{-\frac{1+s(i)}{s(i)+d(i)}}(1 + h(i)) -$$

$$\frac{H(i)(\overline{P(i)})^{1-d(i)}}{1-d(i)}(1 + h(i))^{-\frac{1-d(i)}{s(i)+d(i)}} - Q(i)\overline{P(i)}\left(\frac{1}{1-d(i)} - \frac{1}{1+s(i)} \right)$$

$$= \frac{G(i)(\overline{P(i)})^{1+s(i)}}{1+s(i)}(1 + h(i))^{-\frac{1-d(i)}{s(i)+d(i)}} -$$

$$\frac{H(i)(\overline{P(i)})^{1-d(i)}}{1-d(i)}(1 + h(i))^{-\frac{1+ d(i)}{s(i)+d(i)}} + Q(i)\overline{P(i)}\left(\frac{1}{1-d(i)} - \frac{1}{1+s(i)} \right)$$

Substituting from equations (5.4), (5.5) and (5.7)

$$= Q(i)\overline{P(i)}\left(\frac{1}{1-d(i)} - \frac{1}{1+s(i)} \right) + \frac{Q(i)\overline{P(i)}}{1+s(i)}(1 + h(i))^{k(i)} -$$

$$\frac{Q(i)\overline{P(i)}}{1-d(i)}(1 + h(i))^{k(i)}$$

where, $k(i) = -\dfrac{1- d(i)}{s(i)+d(i)}$

$$= Q(i)\overline{P(i)}\left(\frac{1}{1-d(i)} - \frac{1}{1+s(i)} \right)\left(1 - (1+h(i))^{k(i)}\right)$$

Case 2. Crops traded in the world market when the country concerned is relatively large

To deal with this situation we have specified two inter-related markets, a world market in which the price for the crop is determined by the interaction of world demand and world supply functions for the crop and a domestic market where part of the production is consumed and the rest is exported. As the domestic demand and supply curves, the demand and supply curves in the world market are also assumed to have constant own price elasticity. The formal analysis of this case is presented below with the help of Figures 5.4 and 5.5.

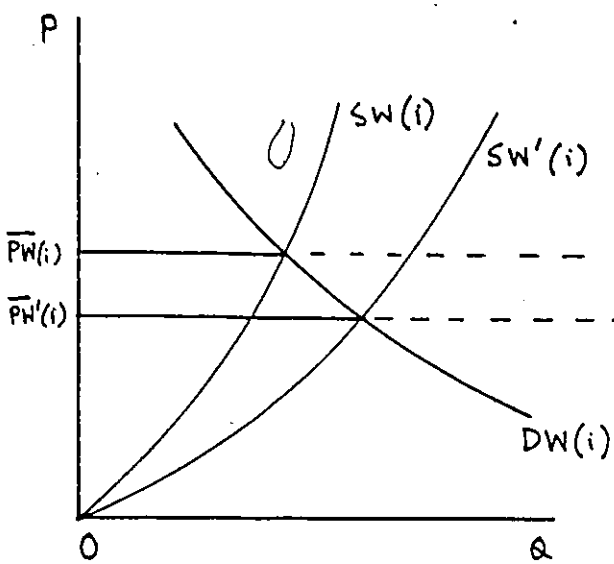

Figure 5.4
Effects of Supply Shift; Case 2: World Market

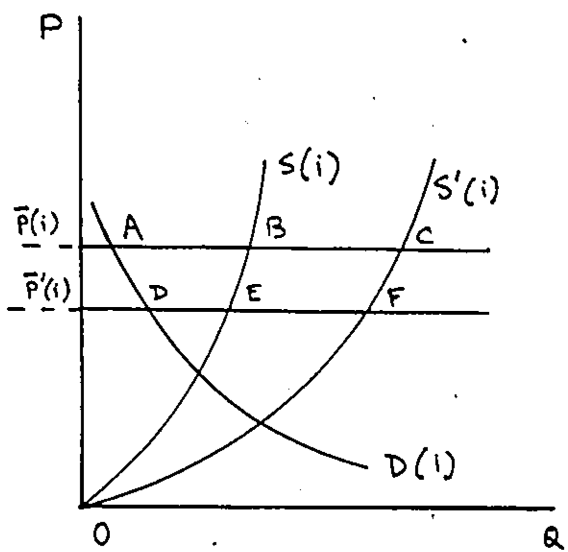

Figure 5.5
Effects of Supply Shift; Case 2: Domestic Market

Figure 5.4 refer to the world market and all the curves, where all the curves and equilibrium values are similar to those of Figure 5.3. To denote their belonging to the world market, the letter 'W' has been included in the definitions of the variables in the figure. The same practice has been followed for other variable definitons used in the text and which have relevance to the world market. Figure 5.5 is similar to Figure 5.3 except that the prices are not determined in this market. The prices prevailing in the world market are assumed to be refleced here.

As seen from the figures, due to a shift in the supply of crop i in the country experiencing technical change in it, the world supply curve shifts from SW(i) to SW'(i). The equilibrium price in the world market consequently falls from $\overline{PW}(i)$ to $\overline{PW}'(i)$. The changes in different measures of benefit in the domestic market are given by:

(5.15) Change in consumers surplus=area $A\overline{P}(i)\overline{P}'(i)D$

(5.16) Change in producers surplus=area OEF-area $B\overline{P}(i)\overline{P}'(i)E$

(5.17) Change in total surplus =area OEF - area BADE

To evaluate these areas we have to express the functions of Figures 5.4 and 5.5 in algebraic notation. While those for Figure 5.5 are similar to those for Figure 5.3, we shall introduce the explicit functions for the curves of Figure 5.4 only in the following discussion. This will enable us to compute the new price resulting from a technical change in the production of crop i in the country concerned. These prices will, in turn, be used to measure the actual areas specified in equations (5.15) through (5.17).

Using the same method as described above and identifying the world market values by adding the letter 'W' in their symbolic definitions, we have

(5.18) World demand function: $QDW(i) = HW(i)\{PW(i)\}^{-dW(i)}$

(5.19) World supply function (original):

$$QSW(i) = GW(i)\{PW(i)\}^{sW(i)}$$

(5.20) World supply function (after shifting):

$$QSW'(i) = (1 + b(i)h(i))hW(i)\{PW(i)\}^{sW(i)}$$

where b(i) is the share of the country concerned in world trade.

Now using the same derivation techniques as described in equations (5.12) and (5.13), the following relationship can be established to be used in subsequent computations:

(5.21) $PW'(i) = PW(i)\{1 + b(i)h(i)\}^{-1/(sW(i)+dW(i))}$

Derivation of various mathematical expressions

As in the previous case, evaluation of definite integrals will provide the basis of our derivations. The formal process of derivations and the outcome are described below:

(5.22) Change in consumers surplus

$$= \text{area } A\overline{PW}(i)\overline{PW}'(i)D$$

$$= \int_{\overline{PW}'(i)}^{\overline{PW}(i)} H(i)(\overline{PW}(i))^{-d(i)} dPW(i)$$

$$= \frac{1}{1-d(i)}(H(i)(\overline{PW}(i))^{1-d(i)} - H(i)(\overline{PW}'(i)^{1-d(i)})$$

(5.23) Change in producers surplus

$$= \text{area OEF} - \text{area } B\overline{PW}(i)\overline{PW}'(i)E$$

$$= \int_{0}^{\overline{PW}'(i)} h(i)G(i)(PW(i))^{s(i)} dPW(i) - \int_{\overline{PW}'(i)}^{\overline{PW}(i)} G(i)(PW(i))^{s(i)} dpW(i)$$

$$= \frac{h(i)}{1+s(i)}G(i)(\overline{PW}(i))^{1+s(i)} - \frac{1}{1+s(i)}(G(i)(\overline{PW}(i))^{1+s(i)} - G(i)(\overline{PW}'(i))^{1+s(i)})$$

Finally, we have

(5.24) Annual benefit, AB(i)

$= \text{area } A\overline{PW}(i)\overline{PW}'(i)D + \text{area } OEF - \text{area } B\overline{PW}(i)\overline{PW}'(i)E$

Substituting from equations (5.22) and (5.23)

$$= \frac{H(i)(\overline{PW}(i))^{1-d(i)}}{1-d(i)} - \frac{H(i)(\overline{PW}'(i))^{1-d(i)}}{1-d(i)} + \frac{h(i)G(i)(\overline{PW}'(i))^{1+s(i)}}{1+s(i)} - \frac{G(i)(\overline{PW}(i))^{1+s(i)}}{1+s(i)} + \frac{G(i)(\overline{PW}'(i))^{1+s(i)}}{1+s(i)}$$

$$= \frac{H(i)(\overline{PW}(i))^{1-d(i)}}{1-d(i)} - \frac{G(i)(\overline{PW}(i))^{1+s(i)}}{1+s(i)} + \frac{G(i)(\overline{PW}'(i))^{1+s(i)}(1+h(i))}{1+s(i)} - \frac{H(i)(\overline{PW}'(i))^{1-d(i)}}{1-d(i)}$$

Substituting from equations(5.4) and (5.5)

$$= \frac{QD(i)\overline{PW}(i)}{1-d(i)} - \frac{QS(i)\overline{PW}(i)}{1+s(i)} + \frac{G(i)(\overline{PW}'(i))^{1+s(i)}(1+h(i))}{1+s(i)} - \frac{H(i)(\overline{PW}'(i))^{1-d(i)}}{1-d(i)}$$

Substituting from equation (5.21)

$$= \frac{QD(i)\overline{PW}(i)}{1-d(i)} - \frac{QS(i)\overline{PW}(i)}{1+s(i)} + G(i)(\overline{PW}(i)^{1+s(i)}(1+b(i)h(i))^{-\frac{1+s(i)}{sW(i)+dW(i)}}(1+h(i)) - \frac{H(i)(\overline{PW}(i))^{1-d(i)}}{1-d(i)}(1+b(i)h(i))^{-\frac{1-d(i)}{sW(i)+dW(i)}}$$

Case 3. Crops traded in the world market when the country concerned is relatively small

In this case since the crop is traded in the world market and since domestic producers cannot influence the world price level (by assumption), the demand curve facing them is horizontal, while the properties of the supply curve remain the same as before. The formal analysis of such a situation is presented through Figure 5.6.

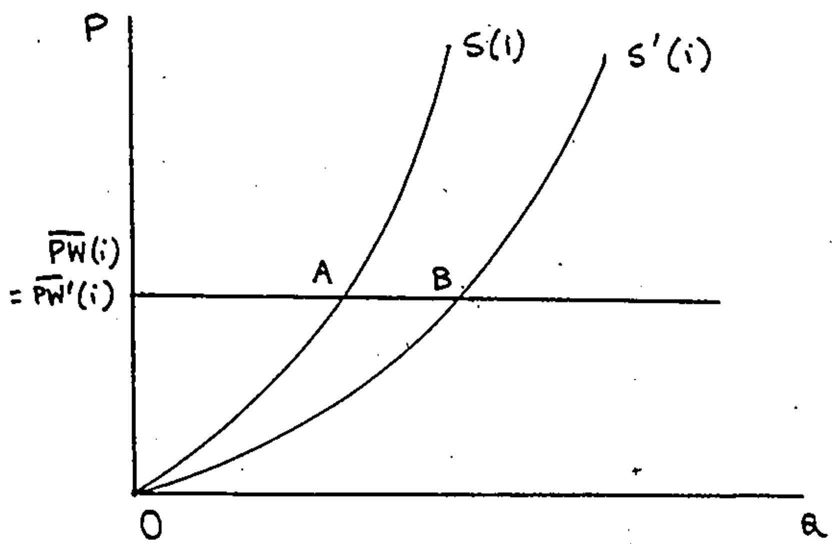

Figure 5.6 Effects of Supply Shift; Case 3

The important thing to note here is that even after an increase in supply by the country concerned, the price level does not change, as it did before. The various measures of benefit in this case are given by:

(5.25) Change in consumers surplus = nil

(5.26) Change in producers surplus = area OAB

(5.27) Change in total surplus = area OAB

The mathematical expressions for the relevant area described in equations (5.26) and (5.27) is given by:

(5.28) Change in producers surplus = area OAB

$$= \int_0^{\overline{PW}(i)} (1+h(i))QS(i)dPW(i) - \int_0^{\overline{PW}(i)} QS(i)dPW(i)$$

$$= \int_0^{\overline{PW}(i)} h(i)QS(i)dPW(i)$$

Substituting from equation (5.5)

$$= \int_0^{\overline{PW}(i)} h(i)G(i)(\overline{PW}(i))^{s(i)}dPW(i)$$

$$= \frac{h(i)}{1 + s(i)} G(i)(\overline{PW}(i))^{1+s(i)}$$

Substituting ~~xgxix~~ from equations(5.5) and (5.7)

$$= \frac{h(i)}{1 + s(i)} Q(i)\overline{PW}(i)$$

Therefore,

(5.29) AB(i) = Change in total surplus

= area OAB

$$= \frac{h(i)}{1 + s(i)} Q(i)\overline{PW}(i)$$

It is interesting to note that equations (5.29) and (5.14) can be shown as special cases of equation (5.24). In equation (5.29) we have b(i) = 0, while in equation (5.14) we have b(i) = 1, s(i) = sW(i) and d(i) = dW(i) in terms of equation (5.24)

Finding total benefits from AREA

Equations (5.14), (5.24) and (5.29) described above express the benefits from a shift in the supply curve due to technical change in terms of known values and the shift parameter, h(i). All these benefits are expressed in annual terms. The effects of a technical change in crop production, on the other hand, extend beyond that period. A measure of total benefits from AREA can be obtained by summing the discounted present values of all these annual benefits for the entire life of the project. Since the future values are unknown to us, we have used two assumptions to arrive at this sum. These are:

(a) The effects of technical change in agriculture from a particular research and extenstion activity will be realized for a period of 'q' years after the introduction of the new technique.

(b) The values of annual benefits in future years will be the same as that in the current years.

The idea implicit in the first assumption is that returns from AREA do not persist for an infinite length of time. The efficiency of the new techniques begins to decline after a certain period despite continued efforts to preserve the same. The second assumption stipulates that once equilibrium is established the values of all the variables and parameters appearing in the benefit functions will not change until the end of the benefit period of 'q' years. This assumption may result in some imprecisions in the estimates. Given that the farmers slowly adopt the new technology and that the yield decline is spread over several years, the annual benefit function for any crop, ceteris paribus, takes the shape indicated in Figure 5.7 for any particular h(i).

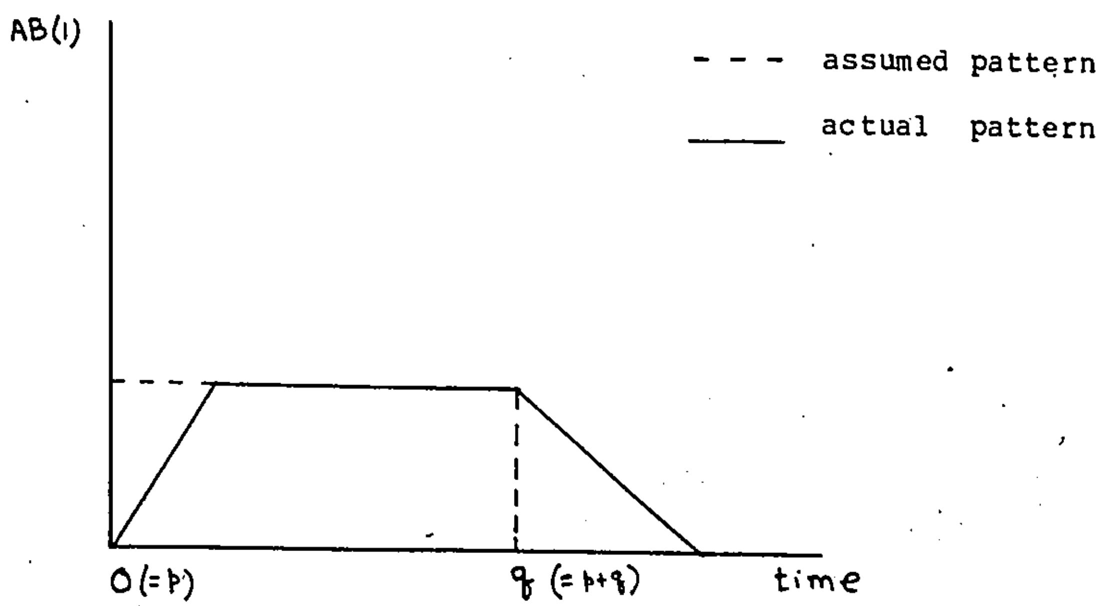

Figure 5.7 Time Profile of the Benefit Function

If the slopes of the benefit function at either end are the same, the over and under estimates will cancel each other. In the actual pattern, the slope of the rising part is more likely to exceed that of the falling section for several reasons: (a) advances in modern communication techniques will speed up the spread of new technological knowledge, (b) most of the developing countries including Bangladesh already possess a network of extension programmes which makes adoption easier and faster, and (c) maintenance research and extension activities envisaged in the present model will tend to arrest the rate of yield decline. Consequently, the assumption of a constant stream of benefits will, in all probability, result in an under estimate of the benefit. This procedure is consistent with the approach taken in other parts of the model. Whenever a choice of specification has been made we have tended to under estimate the benefit and over estimate the cost.

We have, furthermore, assumed that a research programme for any crop initiated at the beginning of year one will be complete by the end of year 'p', after which only recurring costs of extension and maintenance research will have to be incurred. Based on all the three assumptions outlined above, it is possible to express the total benefits for each crop in terms of annual benefits in the following manner:

$$(5.30)\quad TB(i) = \sum_{t=p}^{p+q} AB(i)\{1+r\}^{-t}$$

where,

TB(i) : total benefits expected from research and extension activities in crop i

r : rate of discount

V.5.3 The cost functions

The second important component of our model is the analysis of costs for AREA. The usual information available on the cost aspects of AREA are the figures on total expenditures on such activities and the consequent advancements in the yields per unit of land. If other things remain the same, an 'h' per cent increase in yield will generate an 'h' per cent shift in the supply function.14 With no additional information available, the only practical approach to framing a cost function is to assume a linear relationship between the shift parameter and the costs of AREA. Our present study is based on this assumption and the formal method of developing the function is described below.

Suppose that in any particular country a total sum of RC(i) dollars were spent on agricultural research during a given period of time and that this resulted in a shift of the supply function by h**(i) per cent, where h** refers to the measurement of percentage shifts in absolute unit.

Then, assuming that a linear relationship holds, the cost for obtaining a one per cent shift in the supply function is given by $RC(i)/h^{**}(i) = v^{**}(i)$, say, which is the slope of the cost function. The formal function can now be written as:15

$$(5.31) \qquad RC(i) = v^{**}(i)h^{**}(i)$$

We have already mentioned that in the present study the shift parameter, $h(i)$, is measured as a proportion of unity. The relationship between $h^{**}(i)$ and $h(i)$ is given by:

$$h^{**}(i)/100 = h(i)$$

which is equivalent to

$$(5.32) \qquad h^{**}(i) = 100h(i)$$

Substituting this into equation (5.31)

$$(5.33) \qquad RC(i) = v^{**}(i)100h(i)$$
$$= 100v^{**}(i)h(i)$$
$$= v(i)h(i), \quad \text{where } v(i) = 100v^{**}(i)$$

Equation (5.33) describes the cost functions for agricultural research. In the absence of any knowledge about the actual costs of extension and maintenance research, the simple method to approximate it is to assume that the money spent on such activities every year is a fixed proportion of the total costs of agricultural research, and let this proportion be denoted by e(i). Then the total costs of extension and maintenance research, EC(i) for a project of 'q' years' life span, beginning from 'p+l' years from now, is obtained from:

$$(5.34)\quad EC(i) = \sum_{t=p}^{p+q} e(i)RC(i)/(1 + r)^t$$

Substituting from equation (5.33)

$$= \sum_{t=p}^{p+q} e(i)v(i)h(i)/(1 + r)^t$$

The total costs for AREA in crop i, TC(i), is then given by:

$$\begin{aligned}(5.35)\quad TC(i) &= RC(i) + EC(i)\\ &= v(i)h(i) + \sum_{t=p}^{p+q} e(i)v(i)h(i)/(1+r)^t\\ &= \{v(i) + \sum_{t=p}^{p+q} e(i)v(i)/(1+r)^t\}h(i)\\ &= w(i)h(i)\end{aligned}$$

where,

$$w(i) = v(i) + \sum_{t=p}^{p+q} e(i)v(i)/(1+r)^t$$

It should be noted that in the above formulation, all of the research cost is attributed to the initial year, rather than spreading it over 'p' years. So this part of the TC(i) is over estimated. As it is very difficult to get disaggregated data on the costs of research, with emphasis on its time profile, the other alternatives we had were either to specify some sort of distribution for it or to lump everything on the 'p'th year. To be on the conservative side, we have preferred to discard both of them and attribute all the costs on the first year.

V.5.4 The interactions

Thus far we have been able to develop the benefit and cost functions for AREA and express these functions in terms of the shift parameter, h(i). Now the task remains to find the optimum values for the shift parameter from the interplay of the benefit and cost functions, which we shall denote by h*(i).

First of all, it should be pointed out that the shift parameter is closely linked to the real physical world. This connection automatically fixes some boundary or limiting values to it. In this study, the values for h(i) are restricted to lie in a finite range. The lower limit of this range, termed h(i)L, is set by the realization that to be economically meaningful the values of h(i) must be non-negative, i.e., greater than or equal to zero. The upper limit to the range, on the other hand, is determined by biological factors and by the scientific capabilities of the country concerned, and is denoted by h(i)U. Because the optimum h(i), yielded by solving the equations of the model, may not always be physically attainable, we have introduced the concept of "effective" supply shift, symbolized by h'(i). The values for h'(i) are calculated by the following method: ___________

(5.36) if $h(i)L \leq h^*(i) \leq h(i)U$, then $h'(i) = h^*(i)$

(5.37) if $h^*(i) < h(i)L$, then $h'(i) = h(i)L = 0$

(5.38) if $h^*(i) > h(i)U$, then $h'(i) = h(i)U$

In using the above model for determining the effective h(i), two separate cases have been considered, depending on the availability of the funds for AREA. These are:

Case 1 : No constraint on the funds for AREA.

Case 2 : The funds for AREA are limited.

Case 1. Unconstrained funds

For crops with non-linear total benefit curves, optimum values for the shift parameter, h(i), are given by solving the following equation:

(5.39) $dTB(i)/dh(i) - dTC(i)/dh(i) = 0$

subject to

(5.40) $\{TB(i) > TC(i)\}_{h(i) = h^*(i),\ h'(i)}$

The condition imposed by equation (5.40) ensures the occurence of a positive net benefit and is equivalent to the positive profit conditions in a standard maximization problem. If this condition is not satisfied for any particular crop, it is of no use to invest in research and extension programmes for it. Throughout the computation, this condition will be checked for every value of $h^*(i)$ or $h'(i)$ and unless it is satisfied these values will not be utilized further.

Since we have specified linear total cost curves for all crops, the solution for optimum $h(i)$ for crops which have linear total benefit curves as well (a possibility recognized in Case 3 of the benefit functions) are different from above. Here it is possible to conceive of three types of situations:

(5.41) if $dTB(i)/dh(i) < dTC(i)/dh(i)$, then $h^*(i) = 0$

(5.42) if $dTB(i)/dh(i) > dTC(i)/dh(i)$, then $h^*(i) = \text{infinity}$

(5.43) if $dTB(i)/dh(i) = dTC(i)/dh(i)$, then $h^*(i)$ can assume any value between zero and infinity

Case 2. Constrained funds

We now relax the assumption of the previous discussion and assume that a fixed amount of funds are available for spending on AREA, which shall be denoted by FARE (representing the phrase Funds Available for Research and Extension). The problem now is to allocate this money among various crops for research and extension activities in such a way that total benefit from them is maximized.[17]

We can express combined total benefit, CTB, from technical change in all crops by

$$(5.44)\quad CTB = \sum_{i=1}^{n} TB(i)$$

The problem now becomes a non-linear programming problem of maximizing the CTB subject to the constraint on the funds for AREA . This can be expressed mathematically as

$$(5.45)\quad \text{Maximize } CTB = \sum_{i=1}^{n} TB(i)$$

subject to

$$FARE \geq \sum_{i=1}^{n} w(i)h'(i)$$

To solve it we express the objective function in terms of a Lagrangian multiplier, 'z'

$$(5.46)\quad \text{Maximize } L^* = \sum_{i=1}^{n} TB(i) + z(FARE - \sum_{i=1}^{n} w(i)h(i))$$

where L* is the new objective function.

The first order conditions for maximizing the above function are given by:

$$(5.47)a\quad \partial L^*/\partial h(1) = TB(1)/\ h(1) - zw(1) \leq 0;\ \text{if} < 0, h^*(1)=0$$

. . . .

$$(5.47)n\quad \partial L^*/\partial h(n) = TB(n)/\ h(n) - zw(n) \leq 0;\ \text{if} < 0, h^*(n)=0$$

$$(5.48)\quad \partial L^*/\partial z = FARE - \sum_{i=1}^{n} w(i)h'(i) \geq 0;\ \text{if} > 0, z = 0$$

Due to the presence of upper limits on the h(i)'s and as some crops have linear total benefit and total cost curves for AREA, the ~~solution~~ of the above problem is complicated. We must stipulate a search process to obtain a solution which comprises several steps. In this process the allocation of fundsto the different crops is carried out gradually, introducing the crops in terms of their benefit yielding potential, relative to the costs of research and extension. In this context, it will be useful to define two new variables pertaining to the funds. These are CERE, which stands for cumultive expenditure on research and extension, and FLFA, which represents the funds left for further allocation. These two variables will assume new values at the end of each stage of allocation. Obviously, we have

(5.49) FLFA = FARE - CERE

Step 1

Let us divide the crops into two sets such that the first f of them {Q(1), Q(2).......Q(f)} have non-linear total benefit functions while those for the remaining n-f crops {Q(f+1), Q(f+2).......Q(n)} are linear.16

Now we define two new variables N(g) and M(j) in the following way:

$$(5.50)\quad N(g) = \{dTB(g)/dh(g) - dTC(g)/dh(g)\}_{h(g) = 0}$$

$$g = 1,\ 2,\ \ldots\ldots.f$$

$$(5.51)\quad M(j) = dTB(j)/dh(j) - dTC(j)/dh(j);$$

$$j = (f+1),\ \ldots\ldots.n$$

Without any loss of generality we can assume that the crops are arranged in such a way that

$$(5.52)\quad N(1) \geq N(2) \geq \ldots\ldots. \geq N(f), \text{ and}$$

$$(5.53)\quad M(f+1) \geq M(f+2) \geq \ldots\ldots. \geq M(n)$$

Step 2

Next, we define M*(k) by the following relation:

$$(5.54)\quad M^*(k) = \text{Maximum } \{M(f+1),\ M(f+2), \ldots\ldots M(n)\};$$

$$k = 1\ldots\ldots.(n-f)$$

On account of the assumption of equation (5.53), we have

$$(5.55)\quad M^*(1) = M(f+1)$$

Step 3

Before beginning the process of further computations, it should be recognized that there may be two distinct initial conditions. These are:

(5.56) $N(1) > M^*(1) = M(f+1)$, or

(5.57) $N(1) \leq M^*(1) = M(f+1)$

The formal solution method will be slightly different depending on which of the above conditions are satisfied. The present analysis assumes that the first condition is satisfied, but the study can easily be modified to accommodate the possibility that the second condition holds. To begin with, we take the first 'a' crops from among those of the first set defined above, such that

(5.57) $N(a) > M^*(1)$, and

(5.58) $N(a+1) \leq M^*(1)$

The quasi-optimum values for the shift parameters are then computed for these 'a' crops by solving the following equations:

(5.60) $dTB(g)/dh(g) - dTC(g)/dh(g) = M^*(1); \quad g = 1.......a$

It should be noted that the values of h(i) emerging from solving the relations implied in equation (5.60) above, have been termed as quasi-optimum since, as we shall see now, they may change depending on the outcome of the subsequent operations. These values will be distinguished from the old ones with additional superscripts. The quasi-value for optimum h(i) will be denoted by $h^{*''}(i)$ and that for effective h(i) will be denoted by h''(i). Now from these h*''(g)'s we compute h''(g)'s by following the equations (5.36) to (5.38) described in page 175 of the text. It may be pointed out that if $h^{*''}(g) < h(g)U$, then $h''(g) = h^{*''}(g)$ and if $h^{*''}(g) > h(g)U$, then $h'(g) = h(g)U$. In other words, the value of effective h(g) is liable to change if the quasi-optimum h(g) is less than the upper physical limit specified for crop Q(g) while the effective h(g) will be stable and equal this limit if the quasi-optimum h(g) exceeds this limit.

Now we find CERE from the following relation:

$$(5.61) \quad \text{CERE} = \sum_{g=1}^{Q} w(g)h'(g) + \sum_{g=1}^{Q} w(g)h''(g)$$

The right hand side of equation (5.61) has two closely similar terms. However, there is no overlapping. Crops, for which the h'(g) values dominate, will show up with null values for h''(g) and the reverse will be true for crops with the h''(g) values ruling.

Step 4a

If FARE = CERE, allocation is done to the first 'a' crops only, because in this case FLFA is zero and new crops need not be considered. The share of each crop in the allocation is given by $w(g)h'(g)$ or $w(g)h''(g)$.

Step 4b

If FARE < CERE, the allocation problem is solved with the help of the equations (5.47) and (5.48) reduced to 'a' crops only. Here, again, there is no need to consider the remaining crops and the allocation of funds to each crop will be given by the respective $h'(g)$'s multiplied by $w(g)$'s.

Step 4c

If FARE > CERE, FLFA is positive and this should be spent on crop $Q(f+1)$ upto the point where $h'(f+1) = h(f+1)U$ (or at any point before that if the fund gets exhausted). Next a new CERE value is calculated by adding $w(f+1)h'(f+1)$ to the old CERE. If FARE is still greater than this CERE, a new M^*, say $M^*(2)$, is selected which replaces $M^*(1)$. Now from the first 'a' crops those with $h^{*''}(g) < h(g)U$ are again introduced for reconsideration along with a new group of crops $\{(a+1)$ to $b\}$ from the first set such that

(5.62) $N(b) > M^*(2) = M(f+2)$, and

(5.63) $N(b+1) \leq M^*(2) = M(f+2)$

This will also change the values for CERE and FLFA and the steps 2 to 4 are repeated with these values and new crops (if necessary).

Finally, the process outlined in steps 2 to 4 will have to be continued until FARE = CERE, i.e., FLFA = 0; or until all the n crops have been allocated funds to attain respective h(i)U's.

VI 6 Summary of the Chapter

The major accomplishment of this chapter has been the development of a formal model to allocate funds for AREA among various crops which is summarized below. The importance of the model stems from three observations. First, we have found that so far no such model has been formulated by the economists. Second, we observed that technical progress in agriculture can proceed along different directions (apart from the question of chosing between crops or agricultural activities) and the optimum direction can only be selected through an in depth study of the subject. Third, it was found that in the developing countries (using the experience of Bangladesh as a typical example) the allocation of funds for AREA have failed to satisfy the criterion of optimality.

As a prelude towards developing the model, the chapter also demonstrated that in the case of agricultural innovations, it is not necessary to distinguish between input and output as the medium of development. In most of the instances, the input based technology in agriculture is uniquely related to some particular output. In other words, the choice between input and output to be developed is not mutually exclusive, but can be made simultaneously.

The formal model presented in this chapter has three integral parts. In the first part the total benefits from the postulated technical changes in crop production have been expressed as functions of equilibrium prices and quantitities, demand and supply parameters and the supply shift parameter. In deriving the expressions for total benefits three different exchange situations were analysed: a closed economy, an open economy where the country concerned has a perceptible influence on world price and an open economy where the influence of the country is negligible. In addition, the possibilities that the benefits may extend over several time periods have also been considered. In the second part the total cost functions for achieving the technical changes were formulated in terms of the shift parameter. Both the costs of research and the recurring costs of extension and maintenance research were incorporated. The final part of the model has combined these two functions to find the optimum and/or feasible values for the suppy shift in the context of an unlimited supply of AREA funds and also when these funds are limited. The values of the shift parameter obtained from the final part can be substituted into the total benefit and total cost functions to find the magnitudes for such variables. In addition, these values may be used to find the distribution of benefits from technical change between consumers and producers.

The model presented here is theoretical. In order to compute various elements of it empirically it is necessary to have the information on the relevant parameters. The purpose of the next chapter is to estimate these parameters from the available data.

FOOTNOTES TO CHAPTER V

1. There are several indications to support this claim. First, the Government of Bangladesh re-organized the Bangladesh Agricultural Research Council in 1973 and shifted its headquarters to a new place to co-ordinate the agricultural research activities of the country. Second, the structure of the remaining research organizations in Bangladesh have been strengthened. Finally, the allocation of funds to AREA has increased considerably in recent years.

2. See First Five Year Plan, Government of Bangladesh, p.318 and I.B.R.D. (1974), p. 73.

3. For example, the U.S.A. is relatively land abundant compared to many countries of the world. Nevertheless, she has shown considerable interest in promoting high yielding seed varieties to be used locally.

4. The rest of the issues raised in Section V.1 are considered in the allocation model presented below. However, the analysis of the distributional effects of technical change incorporated in the model is partial as we did not have enough information or time to examine the effects on factor income or employment. The analyses of Chapter III (Section III.7) and Chapter IV (Section IV.3) indicate that development of the bio-chemical technology will help increase the employment of labour and that this increase will be greater if more emphasis is placed on jute relative to rice. For a detailed discussion on these aspects of technological change in the agricultural sector of Bangladesh, the reader is referred to Ahmad (1980).

5. The basis of our claim here is, of course, the articles published in the leading journals and the dissertation abstracts printed in accessible periodicals. Although attempts have been made to be thorough in the search, the chances of oversight cannot be ruled out completely.

6. The term "shift parameter" is common to the studies related to this area. It denotes the magnitude by which the supply curve has shifted to the right on account of technical change in the production of any particular crop. Another common name for this concept is "supply shift". In this study both have been used interchangeably to identify the amount by which the supply curve will shift due to a postulated technical change. In addition the conventional connotation of the term described above has also been retained.

7. See Ramalho de Castro (1974), p.82.

8. For an excellent survey of this concept and its relevance to practical analysis, see Winch (1971) and Sugden (1979).

9. The idea of compensated demand curve differs from that of market demand curve. The former is unobservable and is constructed by adjusting the income of the consumer to keep his level of utility constant. Our study uses the concept of market demand curve, which can be estimated from observable data. This will result in some imprecesion in the measurement of the benefits (except when the market demand curve exhibits zero income effect or is horizontal, i.e., case 3 of the benefit functions) which is discussed below:

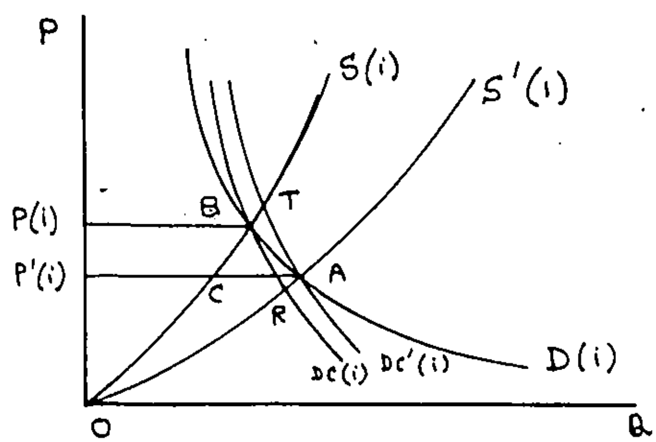

Figure 5.8 Market and Compensated Demand Curves

Figure 5.8 is similar to Figure 5.3 below, except the fact that it has two new demand curves, DC(i) and DC'(i), which represent the compensated demand curves in terms of price P(i) and P'(i) respectively. If DC(i) is the true curve, the use of D(i) will overestimate consumers surplus by the area ARB. On the other hand, if DC'(i) is the true curve, the surplus is underestimated by the area ABT. The magnitudes of these imprecisions are, fortunately, not very serious. In a recent article Willig (1976) has shown that the imprecisions mentioned above are usually overshadowed by the unavoidable error associated with the estimation of the demand curve itself.

10. Since some of the factors remains fixed in the short run (which, incidentally, is our focus of attention), the concept of producers surplus is relevant in that market period. It may be argued that this concept has no relevance in the long run, where all the factors of production are allowed to vary. Because, in that case, the normal profit is included in the cost function (as in the short run) and if there is any surplus or excess profit, new producers will enter to wipe that out.

11. Short run is the relevat time period for this study because in extending the model to future years for policy simulation experiments, we have assumed that nothing else changes other than those induced by the policy variables.

12. This h(i) represents the supply shift parameter referred to in Footnote 6, above. As we shall see below, it is measured in such a way that a one per cent shift reads .01 and so on.

13. The process of computing definite integrals has been discussed in details in Allen (1968), pp. 384-390.

14. The term "yield" has been used here to represent the average yield per unit of land. This is the only form in which the yield data is readily available and it reflects the effects of several factors apart from that of the new seeds. If this definition is accepted, the statement can be proved as follows:

The production function prior to technical change is

(5.64) $Q(i) = y(i)L(i)$

where,

$Q(i)$: amount of crop i produced
$y(i)$: yield of crop i per unit land allocated to it
$L(i)$: amount of land in crop i

Let us denote the post-technical change variables by a superscript ('). Then following an 'h(i)' per cent increase in the yield, the new production function becomes

$$(5.65)\quad Q'(i) = y'(i)L(i)$$
$$\{1 + h(i)\}y(i)L(i)$$
Substituting equation (5.64)
$$= \{1 + h(i)\}Q(i)$$

It should be mentioned that, the above relation may not hold if the actual yield from seed improvement only was considered. However, since the bio-chemical technology is considered to come as a package input as the responsibility of the public sector to provide them through research and extension services, it is difficult to conceive of a situation where the yield increases due to the seed only.

15. Ideally, we would like to have a research cost function described by the following equation:

$$(5.66)\quad RC(i) = RC(i)\{v^{**}(i), h^{**}(i)\}$$

where RC(i) is likely to exhibit increasing marginal costs. The reason for using linear specification for it in the text is the absence precise information on the true form.

16. The symbol Q(i) was used in equation (5.7) above to represent the equilibrium quantities of crop i. Since there is no interaction, we have used the same symbol here and in Footnote 14 above to represent the crop itself, rather than the equilibrium value for it.

17. The use of constrained funds in the future years implies that the shadow discount rates will be the appropriate Lagrangian multipliers which assume different values in different periods. In this study we have assumed that they are approximately equal and that they can be represented by the long term interest rate.

CHAPTER VI

ESTIMATION OF THE PARAMETERS

VI.1 Introduction

In Chapter V, we have developed a model to analyse the cropwise effects of investing resources in AREA in Bangladesh. It was shown that the benefits from technical change in agriculture can be measured through simple mathematical expressions involving observable initial equilibrium values for prices and quantities, some parameters of the demand and supply curves in Bangladesh and in the world market, and a shift parameter to reflect the movement of the supply function resulting from the expected technical progress. The optimum value for this shift parameter was, in addition, observed to depend on the parameters of research and extension costs, the resulting benefits, and a physical upper limit to technological progress. The main reason for developing the above mentioned model was to establish a guideline for allocating the funds for AREA among various crops in Bangladesh. The works reported in this chapter as well as in the following one seek to fulfil that purpose.

We have already observed in Chapter III that although the farmers in Bangladesh grow various crops, it is neither meaningful nor feasible to focus attention on all of them. Most of these crops constitute a very small proportion of total agricultural output of the country. In addition, the relevant data for the study are not available for a large number of crops. Finally, the size and scope of the present study is an increasing function of the number of crops included in the analysis. On account of these considerations, we have concentrated on four crops only, namely, jute, rice, sugarcane, and tea. It has already been mentioned that these crops comprised more than ninety per cent of the total cropped area of the country throughout the period under study, 1950 to 1978. In terms of market exchange, these crops are quite different. While rice is mainly produced for the internal market, the other crops are generally export oriented. Among the latter group, jute, produced in and exported from Bangladesh, is significant enough to influence the level of world prices. The shares of Bangladesh in the global market for the remaining two crops, sugarcane and tea, are too small to exert any perceptible influence.[1] As a result, the four crops selected for the study will require us to incorporate different types of market exchange specified in Chapter V into the study. It is hoped that the approach developed here will provide a general framework for undertaking similar studies involving other crops or agricultural activities omitted from the present study. Moreover, this framework can easily be extended to similar investigations in countries other than Bangladesh.

The empirical implementation of the allocation model is done in two stages. The first stage, described in this chapter, is devoted to the development and/or selection of various parameters of the model from available statistics and indirect sources. In the second stage, which constitutes the next chapter, the model is actually implemented with the help of these parameters.

The approaches followed by most of the authors in dealing with similar problems were either to obtain these parameters from the estimates of others or to use arbitrary values for them based on some a priori reasoning. The only exception to this generalization was Ayer and Schuh (op. cit.) who derived the parameters from their own econometric study. Unfortunately, in the case of Bangladesh, econometric studies done by others on the agricultural sector do not provide these parameters. On the other hand, we believe that the study will lose much of its appeal and practical usefulness if arbitrary values are used for all or most of these parameters, as has been done in some of the works cited above. As such, we have decided to follow a mixed approach to the problem. First of all, to keep the study brief, efforts will be undertaken to obtain these parameters from reliable recent ecnometric works done by others. Next, attempts will be made to estimate the remaining parameters, as far as possible, by using available published statistics. Finally, if both of the above approaches are unsuccessful for some parameters, plausible parametric values will be specified for them based on economic arguments and comparable evidence.

In Section VI.2 the parameters for the supply function are derived from rigorous econometric estimation. The rest of the parameter estimates are described in Section VI.3. The last section presents a brief summary of the chapter.

VI.2 Estimation of Supply Elasticities

VI.2.1 Introduction

Although both the demand and supply function parameters are necessary for our model, it is the latter which need be estimated for each crop. The reason for this is, as we saw in the last chapter, that for some crops (which are traded internationally by a small country) the demand function parameters do not enter into the model explicitly. In addition, we were able to gather reliable secondary source estimates for the demand parameters for at least one of the four crops under study. As none of the above factors were favourable for the supply function parameters, they had to be estimated separately for each of the four crops. The current section is devoted to such estimation. The section is divided into six subsections. Subsections VI.2.2 and VI.2.3 develop theoretical arguments behind the supply functions (a) for crops that compete with each other for the same land, and (b) for crops that do not compete with any other crop in the model for land. The reason for this is that two of our four crops, jute and rice, fall in the first category while the remaining two, sugarcane and tea, possess the second feature. The specification and selection of empirical techniques are done in the fourth and fifth subsections while the results of the empirical analysis are presented in the final one.

VI.2.2 Derivation of supply functions for competing crops

We have seen that jute and rice are the only crops among those under study that compete for the same land. Strictly speaking, jute is grown during the summer and rainy seasons and, as such, competes mainly with aman and aus varieties of rice which are grown during the period.[2] However, due to the non-availability of adequate statistical information, most of the agricultural supply analyses of this region have treated the total rice crop as competitive to jute.[3] In the present study we shall follow the same approach and refrain from making any distinction between various varieties of rice, unless it is specifically needed.

As mentioned in the introduction to this section, the purpose of this subsection and the next is to develop theoretical arguments behind the agricultural supply functions from a neo-classical point of view. These derivations are done in terms of individual farmers. Before estimating them with national data, it is necessary that they should be aggregated to that level. Ideally, such aggregation would require information on several factors including the number of farms in the country and the amount of land suitable for each category of crops in each of these farms. However, this information is hard to find. Similarly, we do not have any reliable study that explains the attitudes of the farmers owning different farm sizes towards land allocation among crops. For these reasons, it was not possible to attempt a formal aggregation. Instead, the aggregate supply functions estimated by us have been formulated by including the same variables as were relevant for the individual farmers. The rationale for this is that if these variables are relevant for individual farmers, they should be so for all of the farmers considered as an entity. It should be pointed out that such aggregation implicitly assumes that the effects of distribution of the fixed factors, land and capital, on production decisions are negligible.

The farmer producing rice and/or jute is assumed to have a fixed amount of land at the beginning of the sowing season each year which is allocated between these two crops in such a way that maximizes his profit. Let each crop be characterized by a neo-classical production function of the following type:

(6.1) $Q(J) = QJ(LJ, IJ, KJ, Z, F, D)$

(6.2) $Q(R) = QR(LR, IR, KR, Z, F, D)$

where,

Q(i) : output of crop i; i = jute or rice

Li : amount of land devoted to crop i

Ki : amount of private capital invested in the production of crop i

Z : a surrogate for non-price variables such as improved technique, farmers' education level

Ii : amount of purchased or hired input applied to the production of crop i

F : index of flood level

D : index of drought level.

It should be noted that in the equations presented in this chapter, the time subscript (t) has been suppressed deliberately. In all the equations involving time series, this subscript is implicit. Where lagged variables enter into the equation, they have been identified by adding the number of lagged years preceded by a minus sign. The subscript has been explicitly introduced only in those cases where it was felt necessary to do so. The surrogate variable, Z, is the same for both the crops and, as we shall see later, also remains unchanged in the context of other crops. The reason for this is that in this study we view it as the services provided by the public sector. When the level of public sector influence is not much the variable should be the same for all crops. Nevertheless, in actual estimation we used a proxy for it which assumed different values for different crops. Finally, due to the absence of disaggregated information on the effects of weather in Bangladesh, we have used the same indices for flood and drought for each of the four crops.

The expected income of the farmer at the beginning of each year's sowing season, when he allocates land between these two crops is given by:

(6.3) $Y(J+R)^* = P(J)^*Q(J) + P(R)^*Q(R) - PI(IJ+IR)$

where,

$Y(J+R)^*$: net income of the farmer expected from the production of jute and rice

$P(i)^*$: expected harvest price of crop i during the time of sowing

PI : price of the purchased input

One remarkable feature of equation (6.3) is that in it neither Z nor K enter as a choice variable facing the farmer. The reason for excluding Z is obvious from its definition given above. Since it is the form of capital provided by the public sector, farmers have little control over it which justifies its exclusion. On the other hand, we have not considered private capital, K, as we are mainly interested in the short run response of the farmers when this variable remains fixed. It may be mentioned, however, that even if our interest was in long run response, it would be difficult to incorporate this variable directly due to non-availability of precise estimates for it.[4]

Now the farmer's objective function is to maximize his expected income by allocating the fixed amount of land he has at his disposal. We can set up a constrained Langrangian maximization problem of the following type to get a solution:

$$(6.4) \quad \text{Maximize } L^{**} = P(J)*Q(J) + P(R)*Q(R) - PI(IJ + IR) + z(LJRF - LJ - LR)$$

where,

L** : the constrained objective function

LJRF : total amount of land available for these crops

z : the Lagrangian multiplier

Assuming that the typical farmer will put some land into jute and some into rice, the first order conditions for maximization are obtained by setting the partial derivatives of L** with respect to the Lagrangian multiplier and the choice variables of the farmer equal to zero

(6.5) $\partial L^{**}/\partial LJ = 0$ implying $P(J)^{*}\{\partial QJ/\partial LJ\} - z = 0$5

(6.6) $\partial L^{**}/\partial LR = 0$ implying $P(R)^{*}\{\partial QR/\partial LR\} - z = 0$

(6.7) $\partial L^{**}/\partial IJ = 0$ implying $P(J)^{*}\{\partial QJ/\partial IJ\} - PI = 0$

(6.8) $\partial L^{**}/\partial IR = 0$ implying $P(R)^{*}\{\partial QR/\partial IR\} - PI = 0$

(6.9) $\partial L^{**}/\partial z = 0$ implying $LJRF - LJ - LR = 0$

From the above equations it is possible to eliminate 'z' and express the demand for land for jute and rice cultivation as functions of the rest of the variables

(6.10) LDJ = LJ{P(J)*, P(R)*, PI, KJ, KR, LJRF, Z; production function parameters}

(6.11) LDR = LR{P(R)*, P(J)*, PI, KR, KJ, LJRF, Z; production function parameters}

where LDi is the amount of land demanded by the farmer for the cultivation of crop i.6

Most of the work on agricultural supply analysis uses a land demand function for measuring supply response.7 The underlying assumption is that as farm output may fluctuate due to weather and other random variables, the land demand function function will measure the true elasiticity of supply, given a fixed proportional relationship between the acreage and the output. However, such a premise is unacceptable to us as the fixed proportionality argument violates the continuity assumption of the neo-classical production function.8 As a result, we plan to use output as the dependent variable and expect that the flood and drought indices of the production function will take care of the weather problems. In addition, a dummy variable will be used in actual estimation to account for the 'abnormal' years.

If we plug in the values of the land demand functions from equations (6.10) and (6.11), and the corresponding purchased input demand functions into their respective production functions, given by equations (6.1) and (6.2), following desired output supply functions can be obtained:9

(6.12) QS(J)* = QSJ*{P(J)*, P(R)*, PI, KJ, KR, LJRF, Z; production function parameters}

(6.13) QS(R)* = QSR*{P(R)*, P(J)*, PI, KR, KJ, LJRF, Z; production function parameters}

where QS(i)* represents the desired supply for crop i in the year to come.

VI.2.3 Derivation of supply functions for non-competing crops

The two remaining crops of our study, sugarcane and tea, fall into this category. The production functions for them are not identical and as such, these crops will be discussed separately.

Sugarcane

As in the case of jute and rice, we can specify a neo-classical production function for sugarcane of the following type:

(6.14) Q(SC) = QSC(LSC, ISC, KSC, Z, F, D)

The definitions of the variables remain the same, and the term 'SC' replaces 'J' or 'R' to represent sugarcane. The expected income of the farmer from the production of sugarcane is given by:

(6.15) YSC* = P(SC)*Q(SC) - PI.ISC

The formal arguments for deriving equation (6.15) are the same as before. The objective of the farmer is to maximize his income represented by equation (6.15). By solving the maximization problem we can get the following demand function for land:

(6.16) LDSC = LSC{P(SC)*, PI, KSC, Z; production function parameters}

Like the preceding case, plugging in the land demand function and the corresponding purchased input demand function into the production function, we can get the desired supply function for sugarcane as:

(6.17) QS(SC)* = QSSC*{P(SC)*, PI, KSC, Z; production function parameters}

Tea

Tea is a perennial crop. Once planted, the trees become productive after a lag of five years and then remain in production for about a century.10 The yield from it, however, fluctuates over the period. It starts with a low level, gradually rises to the peak and stays there for about seventy to seventy five years before beginning to fall. Due to the long time profile with variable yields, the formulation of the supply function for perennial crops has given birth to a great deal of controversy. While some have used a capital-theoretic approach to the problem within a Nerlovian framework, others have suggested the use of irreversible supply functions based on the concept that once more land is planted with a perennial crop due to favourable price, it may be profitable not to remove them if there is a fall in the price. On the other hand, some economists have used simple Nerlovian supply functions with appropriate lags to get the short run supply response.11 It is not the objective of the present study to go into the debates surrounding the methodological issues involving the supply functions of the perennial crops. Since our primary interest is to find short run elasticities, we postulate a short run production function for processed tea of the following type:

(6.18) $QS(T) = QT\{LT(-5), N(RT), N(PT), Z, F, D\}$

where,

LT(-5) is the land area under tea plantation in five years or more prior to the year of tea plucking. This ensures that only productive plants are being considered in the supply function. On the other hand, since tea plantation in Bangladesh is of relatively recent origin, the problem of plants becoming unproductive due to ageing does not arise.

N(RT) is the number of workers engaged in the production activity involving raw tea.

N(PT) is the number of workers engaged in the processing of raw tea. This represents the bulk of the short run costs for converting raw tea into its processed form. It should be mentioned that since both the production and processing of raw tea are usually done by the same entrepreneur, both N(RT) and N(PT) merit inclusion into the short run production function for tea.

The rest of the variables in equation (6.18) are similar to those defined earlier and need no further introduction.

It is very difficult to obtain reliable information on N(RT) or N(PT). However, under perfect competition, the employment of any factor equals the level where its marginal product equals the price in real terms. For labour it implies

(6.19) N(RT) = NRT(WAGR)

(6.20) N(PT) = NPT(WMNF)

where WAGR is the real wage rate in the agricultural sector and WMNF is the real wage rate in the manufacturing sector.

Using the profit maximization method described before and utilizing the equations (6.19) and (6.20) we can get a desired supply function for processed tea as:

(6.21) QS(T)* = QST*{LT(-5), P(T)*, WAGR, WMNF, Z; production function parameters}

Equations (6.12), (6.13), (6.17), and (6.21) are the supply functions for the four crops under study. These functions have been derived from the viewpoint of the individual producer. We have already mentioned that the aggregate supply functions will be formed by keeping the number of variables unchanged. From now on, we shall use these equations as national supply curves. For simplicity, the names of the variables have not been changed in the subsequent analysis where the same variables will now represent national aggregates.

VI.2.4 Specification of the estimating equations

It is not possible to estimate the agricultural supply functions of the last subsection by incorporating all of the theoretically relevant variables. The main reasons for this are two fold:

First, we do not have time series data on some of the variables specified there, and

Second, it is very difficult to quantify some of the variables in physical terms.

In dealing with the first problem, our approach has been to use all those variables for which data could be gathered for a sufficiently long period of time. Labour force employed in the agricultural sector was taken as the indicator of the purchased input. The data for its price, the real wage rate in agriculture, was readily available. Data on the level of capital stock in agriculture, especially on its allocation between various crops could not be obtained and, hence, this variable was not used in the estimating equations. This may not be a serious problem, as the agricultural sector of Bangladesh is still traditional where the use of private capital (such as bullocks and ploughs) can be viewed as proportional to land. Similar problems were encountered in finding a suitable measure for Z, the surrogate for non-price variables. Traditionally, economists have used yield data or a trend variable to capture the effect of technological change in agriculture. However, we have seen in Chapter III that most of the agricultural sector of Bangladesh has yet to experience any technological change or yield improvement. Consequently, the use of such variables as surrogates will be inappropriate in the context of Bangladesh. We rather believe that the total land constraint variable for each crop will serve as a better proxy for the surrogate variable, as many influences of non-price factors are reflected in the availability of agricultural land for cultivation.

In reference to the second problem mentioned at the beginning of this subsection, the non-quantifiable variables in the supply functions are expected price and the desired output for each crop which have been denoted by a superscript (*). Both of these are subjective variables and very difficult to estimate empirically. But, after the seminal work of Nerlove (1958), many authors have attempted to quantify these variables based on different assumptions as to how they are formed. In the following discussions we shall present some of these approaches and incorporate them in our supply models to yield various versions of the estimating equations.

For jute, our basic estimating equation is specified below. The corresponding equation for rice can be developed easily by substituting the proper variables.

$$(6.22)\quad QS(J)^* = a(0) + a(1)P(J)^* + a(2)P(R)^* + a(3)WAGR + a(4)LJRF + \text{error term}$$

where a(j) are regression coefficients, j = 0,1,2,...so on.

Briefly stated the relationship between changes in prices and changes in actual output can be described in three steps:

(a) the effect of changes in current prices on price expectations,

(b) the effect of changes in price expectations on equilibrium or desired output, and

(c) the effect of changes in the equilibrium output on the level of current output.

The various assumptions regarding the formation of price expectations and output adjustments will generate, as we shall see below, the various estimating versions of the supply response model.

The simplest possible approach to the problem is to assume that current year's price expectation is given by the actual price level of last year and that the equilibrium level of output is obtained instantaneously, i.e.,

$$(6.23)\quad QS(J)^* = QS(J)$$

$$(6.24)\quad P(J)^* = P(J)\{-1\}$$

$$(6.25) \quad P(R)^* = P(R)\{-1\}$$

Substitution of equations (6.23) to (6.25) into equation (6.22) yields:

$$(6.26) \quad QS(J) = a(0) + a(1)P(J)\{-1\} + a(2)P(R)\{-1\} + a(3)WAGR + a(4)LJRF + \text{error term}$$

It is interesting to note that above formulation is embedded in the concept of traditional cobweb model and is known as the "naive expectations model".

The naive mechanism for the generation of expectation parameters has been criticized by various authors including Nerlove. He argued that the reactions of the farmers are influenced by changes in the expected "normal prices", which is equivalent to our P(i)* defined above. As to the formation of this normal price expectation, he postulates that it is the actual values of the price variables in the past that determines it. In specifying the way in which past prices exert their influence, more weight should be given to the prices of more recent past which calls for a weighted moving average of the past prices. Nerlove derived an expression of price expectation based on the Hicksian concept of elasticity of expectations.12 If some kind of a expected normal price, P(i)*, is assumed to exist at any point of time, then, in the Hicksian sense, P(i)* can be defined as last period's expected normal price, P(i)*{-1}, modified by some degree of adjustment depending on the elasticity of expectations and the actual price for last period, P(i){-1}. This led to the development of Nerlovian adaptive expectations equations of the following type:

(6.27) $P(J)^* = P(J)^*\{-1\} + b\{P(J)\{-1\} - P(J)^*\{-1\}\}; \quad 0 \le b \le 1$

(6.28) $P(R)^* = P(R)^*\{-1\} + b\{P(R)\{-1\} - P(R)^*\{-1\}\}; \quad 0 \le b \le 1$

The above equations imply that current expected price will be same as the past period's expected price but for an amount proportional to the forecasting error of the past period. For simplicity, we assumed that the price expectation coefficient, 'b', is the same for both the prices. In addition, following most of the empirical works on agricultural supply analysis, we have decided to treat prices of jute and rice separately rather than use them in a single variable expressed in relative terms. The use of ratio of prices has one major disadvantage as it assumes that any change in the prices of jute or rice will produce the same quantitative effect on the dependent variable when the estimation is done in log-linear form. Another reason for using prices as separate variables is that it assumes away some complications that might otherwise show up as the input prices are not influenced by the expectations.

Equations (6.27) and (6.28) satisfy the criterion of being a moving average of past prices with the weights declining as we move further back in time. This can be shown by rewriting them as:

(6.29) $P(i)^* = b.P(i)\{-1\} + (1-b)P(i)^*\{-1\}, \quad i = J, R.$

Equation (6.29) is a first-order difference equation and the solution of it for $P(i)^*$ in terms of $P(i)\{-1\}$ and 'b' yields:

(6.30) $P(i)^* = \sum_{r=0}^{\infty} b(1-b)^r P(i)\{t-r-1\}$

It should be noted that in equation (6.30) we have explicitly introduced the time subscript for clarity of exposition. If the expectation coefficient, 'b', is zero, expected prices do not depend on the past prices in any manner. On the other hand, if b = 1, we go back to the naive expectation model described in equation (6.26).

We now have a different model consisting of equations (6.22), (6.27), (6.28) and (6.23). The reduced form of this model results in the following estimating equation:

(6.31) $QS(J) = a(0)b + a(1)b\ P(J)\{-1\} + a(2)b\ P(R)\{-1\}$
$+ (1-b)\ QS(J)\{-1\} + a(3)\ WAGR + a(4)\ LJRF$
$+ a(5)\ WAGR(-1) + a(6)\ LJRF(-1) +$ error term13

The coefficient a(1)b can be used to estimate the short run elasticity of supply. The estimate of a(1) derivable from the above equation can provide the long run supply elasticity.

So far we have concerned ourselves with an adaptive expectations model in which lags are specified in the independent variables only. An alternative approach to the problem, known as the partial adjustment model, specifies lagged adjustment in the dependent variable. In other words, we no longer assume that farmers adjust their output to the equilibrium level instantaneously (i.e., QS(i)* = QS(i)). If this assumption is dropped, we can specify a Nerlovian adjustment lag as follows:

(6.32) $QS(J) = QS(J)\{-1\}+c\{QS(J)\{-1\}^{*}- QS(J)\{-1\}\}; 0 \leq c \leq 1$

The interpretation of the above output adjustment equation is similar to the adjustment mechanism in the price expectation explained before. In this equation the output adjustment coefficient is represented by 'c'. The farmers are in a position to alter the output in any given period by a fraction 'c' of the difference between the output they would like to plant and the output they actually harvested in the period before. Incidentally, it may be mentioned that the magnitude of 'c' can be considered as the measure of the speed at which actual output adjusts in response to the factors influencing the equilibrium output. When c = 1, the speed is infinite and the desired output is obtained without any lag. On the other hand, c = 0 denies any influence of equilibrium output on its current value. Traditionally, the partial adjustment model has been handled by assuming a naive price expectation model (i.e., P(i)*= P(i){-1}). In other words, equations (6.22), (6.24), (6.25), and (6.32) define the partial adjustment model, the reduced form of which is given by:

(6.33) QS(J) = a(0)c + a(1)c P(J){-1} + a(2)c P(R){-1}
+a(3)c WAGR + a(4)c LJRF+ (1-c)QS(J){-1} + error term

The equations (6.31) and (6.33) based respectively on adaptive expectation and partial adjustment models are very similar in form. In fact, they are distinguished by the existence of WAGR(-1) and LJRF(-1) terms in the former, which may create problems in interpreting these equations.[14]

The traditional partial adjustment model described above is based on the naive price expectation hypothesis. It seems desirable to modify it by stipulating some other specifications of price expectation into the model. Two such modifications will be considered in the following discussions.

Goodwin (1947) suggested a more sophisticated approach to price expectations compared to the naive version. He allowed for a learning process on the part of the cultivators and presented the following price expectation equation:

$$(6.34) \quad P(i)^* = P(i)\{-1\} + g\{P(i)\{-1\}-P(i)\{-2\}\}; \quad -1 \leq g \leq 1$$

Equation (6.34) states that expected price at current period {P(i)*} equals actual price in the last period plus or minus some proportion of the change in actual price between two periods ago and the last period. Muth (1961) has referred to the above as "extrapolative expectations" as it assumes that estimates of future prices are formed by extrapolating the current prices, modifying by a factor 'g', for the most recent observed change in price. Goodwin's formulation, though better than the naive formulation of price expectation, is still naive compared to the declining weight approach specified in equation (6.30), as it assumes that the farmers have a short memory.

Equations (6.22), (6.32), and (6.35) produce the extrapolative expectations model, which reduces to:

$$\begin{aligned}(6.35) \quad QS(J) = {} & a(0)c + (1-c)\ QS(J)\{-1\} + a(1)c\ P(J)\{-1\} \\ & + a(2)c\ P(R)\{-1\} + a(1)cg\ \{P(J)\{-1\}-P(J)\{-2\}\} \\ & + a(2)cg\ \{P(R)\{-1\}-P(R)\{-2\}\} + a(3)c\ WAGR \\ & + a(4)c\ LJRF + \text{error term}\end{aligned}$$

The coefficients of PJ(-1), a(1)c, can be used to determine the short run elasticity of supply in this model while the other coefficients can be utilized to find the long run supply elasticity and the behavioural coefficients.

The last approach we consider to modify the naive expectation version of the traditional partial adjustment model is to include the Nerlovian expectation equations for price, (6.25) and (6.26), directly into the model. For simplicity, we ignore the non-price variables and the combined adaptive expectations and partial adjustment model is obtained as:15

(6.36) QS(J) = w(0)+w(1)P(J){-1}+w(2)P(R){-1}+w(3)QS(J){-1} + w(4)QS(J){-2} + error term

The values of the lag coefficients can be computed from this by comparing it with the structural equations. Theoretically, the above formulation recognizes the importance of both types of lags, lags in the formation of price expectations as well as lags in adjustment on the part of farmers. However, a problem arises because the lag coefficients ('b' and 'c') enter into the equation symmetrically and it is not possible to distinguish one from the other. Economists have often tried to do so on the basis of a priori reasonings. However, in the present study our aim is to develop short run supply elasticities for which we do not have to distinguish the sources of lagged adjustment. The coefficient w(1) can be utilized to compute the short run own price elasticity of supply.

To summarize, the above discussions have yielded five estimating equations for measuring the supply response of jute, namely, equations (6.26), (6.31), (6.33), (6.35), and (6.36). By substituting rice for jute similar supply equations can be generated for rice as well. The estimating equations for sugarcane can also be derived from the above analysis by making minor adjustments. As mentioned before, in the absence of any theoretical knowledge as to how the expectation or adjustment mechanism operates, all of the estimating versions of the equations will be tried in order to examine their respective explanatory power and the equations which appear most satisfactory will be picked for future use.

Since the supply equation for tea is cast in a short run framework and since the gestation period in tea (apart from new plantation) is very small, the framing of estimating equations was easier. The expected price variable was replaced by the current price and the problem of adjusting to the equilibrium output was not considered. The task was further simplified by the fact that time series data were available for all the relevant variables specified in equation (6.21) except those for the surrogate variable, Z, and the production function parameters. The first variable was dropped from estimation, leaving the lagged acreage variable to capture its influences. The non-availability of the production function parameters was a problem common to all crops. The method employed as a solution to this is discussed in the next paragraph.

Before concluding this discussion on the specification of estimating equations, three general points should be mentioned.

First, in the absence of any precise knowledge of the production functions, the supply equations for all four crops have been estimated and reported in both linear and log-linear form.

Second, in all the estimating equations a dummy variable has been introduced for the period 1970-71, to take account of the disturbances created by the political unrest and the liberal struggle.

Third, two indices representing flood and drought (denoted by symbols F and D) were added to each estimating equation to capture the effects of the weather variable. The specifications of the production funcctions described in equations (6.1), (6.2), (6.14), and (6.18) justify such inclusion.16 These indices were constructed from published statistics on rainfall in various parts of Bangladesh in the following manner. The country was divided into four regions and each region's total annual levels of precipitation was weighted by its' share in total agricultural land of the country. The weighted average of these four areas rainfall levels was taken as the level of annual precipitation in the whole country for any given year. An average rainfall figure for the entire sample period was then calculated by taking the simple arithmetic mean of these weighted averages. Next, for each year we measured the deviations of the weighted averages from the mean value. If the difference was positive, it was put in the index of flood and if it was negative, it was included in the index of drought.17 These indices, obviously, pertain to the whole of Bangladesh. On the other hand, tea is grown in some specific regions of the country, and this makes those indices quite irrelevant for tea. However, it was not possible to get the rainfall data separately for the regions where tea is produced. As a result, these variables were not included in the estimating equations for the tea supply function.

VI.2.5 Some problems in estimation

We have now specified the estimating equations for the measurement of the elasticities of supply. In the following discussion we plan to examine the common problems associated with the estimation of similar equations and the techniques that may be applied to overcome them.

Griliches (1961) has argued that most of the variables in agriculture are predetermined and as such, single equation estimating models are appropriate for this sector. Regarding the technique of estimation it is argued that the application of the method of ordinary least squares provides the best linear unbiased estimates of the parameters given that the disturbance term satisfies the following criteria:[18]

$$E\{u(i)u(j)\} = 0, \text{ for } i \neq j \tag{6.37}$$
$$= \text{some constant, } s2, \text{ for } i = j$$

$$E\{u(i)X(i)\} = 0 \tag{6.38}$$

where u(i) is the term for random disturbances, and X(i) is the explanatory variable.

However, a model involving lagged values of the explanatory variables may often fail to satisfy the above criteria, raising questions about the validity of the use of the ordinary least squares technique.[19]

It has been shown that these types of models create the problem of serial correlation in the error terms. Even if the basic model is free from serial correlation, the substitution of the expectation equation is capable of generating auto-correlation in the disturbance term.[20]

Several methods have been suggested to overcome this problem. Klein (1958) assumed that the original disturbance terms are serially independent. This enabled him to find an estimating technique by transforming the model into one of errors in variables. Koyck (1954) developed several estimating techniques based on various assumptions on the relationships between the disturbance term and the lagged dependent variables. His method has been described in Johnston (1972).21 A third method of dealing with this problem is to apply simultaneous equation estimating techniques as done by Behrman (1968), for example. The expectation models described earlier have marked similarity with systems of simultaneous equations. Provided the conditions of identification are satisfied, we can apply the technique of two stage least squares. That is to say, we first estimate Q(i){-1} from a finite term approximation and substitute these values into the second stage estimations. However, his method creates the problem of multi-collinearity among several lagged variables, and may fail to increase the efficiency of the estimates. Malinvaud (1966) has discussed the various estimating techniques in similar situations and has found that:

> "...in spite of the imperfections (of least squares), least squares applied to the autoregressive form is often the best method for estimating a model whose coefficients have a geometric or negative binomial distribution. For

> there are two considerable advantages in this method: the computation involved is fairly simple, it has a fairly high degree of efficiency since it leads to estimates whose variances are smaller that those of other estimates and which are not often too highly biased".22

The estimating technique employed for the models with expectation variables will, therefore, be ordinary least squares. The cost of its use will be that we will not be able to test the hypothesis of the absence of serial correlation. The usual method for testing its presence, the Durbin-Watson technique, is not valid when there are lagged dependent variables. Though Durbin later suggested a test statistic to be used when the above problem exists, his test statistic, unfortunately, applies to large sample experiments only. As the sample size in our equations are small, we are unable to use Durbin's statistic. Consequently, we have to be careful in interpreting the significance of our values for the Durbin-Watson statistics reported along with the estimated equations below.

Finally, it should be mentioned that, since we have not specified any expectation or adjustment mechanisms for the tea supply equations, the application of ordinary least squares technique there will create none of the above problems. The actual results of the estimation for each crop and selection of supply elasticities therefrom is described in the next subsection.

VI.2.6 Selection of supply elasticities

In this subsection we will first report various estimates of the supply functions developed above. These estimates. are done for the period 1950 to 1977. Later in this subsection we present an estimate of the supply elasticity of jute in the world market. The five behaviourial models stipulated in Subsection VI.2.5 yield ten estimating equations (five each for the log-linear and linear versions) for jute, rice, and sugarcane. All of these estimates have been reported in Tables 6.1 to 6.3. The correspondence between the equations reported there and the underlying behaviourial models is as follows:

Equation (6.26) : Naive expectations

Equation (6.31) : Adaptive expectations

Equation (6.33) : Partial adjustment with naive excpectations

Equation (6.35) : Partial adjustment with extrapolative expectations

Equation (6.36) : Partial adjustment with adaptive expectations

For convenience, the equation numbers have not been changed among crops even though they include different variables depending on the crop concerned. For tea, we specified only one estimating equation and the two versions for it (log-linear and linear) are reported in Table 6.4. These tables are analysed in details below.

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TABLE 6.1

ESTIMATES OF JUTE SUPPLY FUNCTIONS

Eqn.	Intercept	PJ(-1)	PR(-1)	QSJ(-1)	QSJ(-2)	WAGR	WAGR(-1)	LJRF	LJRF(-1)	F	D	DUM	D.W.	R^2
6.26a	-1.17 (-.10)	.62 (4.95)	-.15 (-.91)			-.69 (-3.34)		-.73 (.65)		.017 (.29)	-.03 (-.59)	.21 (1.04)	1.50	.81
6.31a	.57 (.08)	.69 (3.75)	-.08 (-.35)	.60 (3.51)		-.29 (-1.03)	.82 (2.84)	.10 (.06)	-.07 (-.04)	-.02 (-.46)	.03 (.38)	-.09 (-.27)	1.85	.81
6.33a	-1.52 (-.21)	.69 (3.15)	-.23 (-.96)	.51 (2.64)		-.38 (-1.13)		.39 (.52)		-.04 (-.74)	-.008 (-.10)	-.09 (-.03)	1.61	.68
6.36a	.54 (.52)	.72 (3.31)	-.19 (-.56)	.51 (2.48)	.19 (.73)					-.02 (-.46)	-.0006 (-.009)	-.08 (-.33)	1.98	.66
6.26b	-67.33 ~~(-.04)~~	32.58 (4.18)	-9.04 (-.56)			-544.07 (-2.56)		.08 (1.14)		11.41 (1.22)	4.41 (.33)	63.15 (.14)	1.61	.77
6.31b	-1956.89 (-1.46)	34.62 (3.12)	3.24 (.14)	.62 (3.57)		-302.83 (-1.15)	807.51 (3.04)	.01 (.12)	.02 (.19)	1.94 (.15)	6.62 (.35)	-574.56 (-.91)	1.82	.78
6.33b	-656.99 (-.47)	36.72 (2.72)	-13.99 (-.58)	.52 (2.52)		-331.75 (-1.03)		.06 (1.12)		-.69 (-.04)	10.64 (.04)	-384.04 (-.47)	1.57	.62
6.36b	-476.92 (-.85)	37.12 (2.80)	-6.44 (-.30)	.53 (2.50)	.27 (1.07)					1.84 (.14)	11.11 (.55)	-529.43 (-.88)	1.92	.60
					PJ^c_{12}	PR^c_{12}	WAGR							
6.35a	-5.59 (-.76)	1.07 (4.57)	.29 (.99)	.53 (3.11)	-.12 (-2.10)	-.11 (-2.51)	-.24 (-.71)	.90 (1.24)		-.05 (-.89)	.04 (.55)	-.22 (-.77)	1.10	.72
6.35b	-959.57 (-.53)	53.40 (2.22)	-11.20 (-.30)	.54 (3.02)	-12.09 (-.74)	-4.50 (-.14)	-429.59 (-1.10)	.10 (1.59)		-5.60 (-.30)	11.34 (.40)	-160.34 (-.19)	.85	.49

Figures in the parentheses are respective t-scores

a. indicates that the estimation was done in log-linear form

b. indicates that the estimation was done in linear form

c. while the remaining variables are defined in the text, Pi_{12} equals Pi(-1)-Pi(-2), i = J,R

TABLE 6.2

ESTIMATES OF RICE SUPPLY FUNCTIONS

Eqn.	Intercept	PR(-1)	PJ(-1)	QSR(-1)	QSR(-2)	WAGR	WAGR(-1)	LJRF	LJRF(-1)	F	D	DUM	D.W.	R^2
6.26a	-10.41	.13	-.02			.26		1.92		.0002	.02	-.10	1.64	.92
	(-5.62)	(.50)	(-.49)			(3.16)		(10.22)		(.01)	(.89)	(-1.93)		
6.31a	-8.61	.11	-.03	.13		.24	-.08	2.09	-.45	-.0005	.002	-.05	1.91	.93
	(-2.05)	(.14)	(-.52)	(.44)		(2.49)	(-.70)	(4.26)	(-.56)	(-.16)	(.42)	(-.40)		
6.33a	-10.67	.13	-.02	-.03		.26		1.97		-.0003	.02	-.09	1.60	.92
	(-4.43)	(.37)	(-.42)	(-.18)		(3.04)		(5.47)		(-.02)	(.84)	(-1.23)		
6.36a	.90	.18	-.11	.58	.31					-.01	-.0001	-.17	2.38	.88
	(.61)	(1.83)	(-1.14)	(2.56)	(1.39)					(-1.61)	(-.003)	(-1.37)		
6.26b	-10567.21	13.46	-4.09			1535.82		.703		-3.16	11.25	-796.14	1.77	.93
	(-5.89)	(.43)	(-.23)			(3.72)		(10.39)		(-.16)	(.38)	(-.98)		
6.31b	-9543.83	5.11	-3.97	.042		1510.97	-406.03	.73	-.05	-3.62	12.56	-667.39	1.86	.94
	(-2.93)	(.13)	(-.20)	(.131)		(3.10)	(-.63)	(4.33)	(-.15)	(-.16)	(.38)	(-.59)		
6.33b	-11012.54	9.64	-3.40	-.052		1566.87		.74		-3.68	11.39	-728.91	1.70	.93
	(-5.09)	(.28)	(-.19)	(-.32)		(3.59)		(5.86)		(-.18)	(.37)	(-.84)		
6.36b	1252.32	88.15	-30.98	.56	.30					-47.08	-42.46	-703.46	2.49	.78
	(.67)	(1.69)	(-.95)	(2.47)	(1.33)					(-1.35)	(-1.35)	(-.44)		
					PR^c_{12}	PJ^c_{12}	WAGR							
6.35a	-10.43	.14	-.03	.11	-.01	.005	.24	1.92		.002	.02	-.11	1.64	.93
	(-5.33)	(.54)	(-.55)	(.39)	(-.91)	(.41)	(2.59)	(9.90)		(.13)	(.99)	(-1.47)		
6.35b	-10075.51	3.73	-14.63	.029	15.99	10.67	1456.59	.70		-3.15	5.16	-567.95	1.67	.94
	(-4.96)	(.089)	(-.54)	(.11)	(.46)	(.58)	(3.29)	(9.84)		(-.15)	(.16)	(-.62)		

Figures in the parentheses are respective t-scores
a. indicates that the estimation was done in log-linear form
b. indicates that the estimation was done in linear form
c. while the remaining variables are defined in the text, Pi_{12} equals Pi(-1)-Pi(-2), i = R,J

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TABLE 6.3

ESTIMATES OF SUGARCANE SUPPLY FUNCTIONS

Eqn.	Intercept	PSC(-1)	PSC_{12}^{c}	QSC(-1)	QSC(-2)	WAGR	WAGR(-1)	$LSCF^{d}$	LSCF(-1)	F	D	DUM	D.W.	R^2
6.26a	-.28 (-.46)	.42 (3.13)				-.19 (-1.64)		1.49 (13.50)		-.005 (-1.79)	.002 (.39)	-.02 (-.13)	1.38	.95
6.31a	-.21 (-.33)	.24 (1.38)		.49 (2.11)		.04 (.29)	.08 (.70)	.92 (1.64)	-.17 (-.25)	-.004 (-1.25)	.002 (.46)	-.06 (-.50)	1.74	.96
6.33a	-.33 (-.54)	.31 (2.47)		.41 (2.55)		-.005 (-.004)		.89 (3.47)		-.004 (-1.52)	.002 (.51)	-.06 (-.54)	1.80	.96
6.35a	-.32 (-.44)	.42 (3.04)	-.006 (-.49)	.37 (2.03)		-.19 (-1.60)		1.50 (13.13)		-.006 (-1.80)	.001 (.21)	-.005 (-.02)	1.47	.95
6.36a	1.04 (1.18)	.06 (.30)		1.08 (4.78)	-.20 (-.79)					-.007 (-2.28)	-.003 (-.62)	.07 (.48)	1.65	.93
6.26b	-3318.74 (-2.42)	1164.76 (3.01)				-766.54 (-1.96)		23.37 (11.80)		-43.59 (-2.41)	.15 (.006)	209.88 (.27)	1.36	.93
6.31b	-2822.51 (-1.91)	689.72 (1.57)		.48 (2.23)		-44.96 (-.09)	226.34 (.56)	17.51 (1.57)	-5.42 (-.45)	-32.34 (-1.85)	2.64 (.11)	-62.35 (-.08)	1.74	.95
6.33b	-2840.84 (-2.28)	869.61 (2.35)		.39 (2.28)		-172.90 (-.40)		14.29 (3.28)		-35.24 (-2.12)	3.81 (.17)	-96.24 (-.14)	1.66	.95
6.35b	-5277.66 (-2.81)	1650.95 (3.31)	-745.52 (-1.47)	.34 (2.15)		-497.63 (-1.18)		24.75 (11.61)		-46.95 (-2.66)	.26 (.01)	-39.41 (-.05)	1.54	.94
6.36b	1115.98 (.82)	70.29 (.15)		1.09 (5.16)	-.12 (-1.07)					-44.21 (-2.41)	19.61 (.70)	638.77 (.71)	1.53	.91

Figures in the parentheses are respective t-scores
a. indicates that the estimation was done in log-linear form
b. indicates that the estimation was done in linear form
c. PSC_{12} = PSC(-1) - PSC(-2); d. LSCF represent total land available for sugarcane.

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TABLE 6.4

ESTIMATES OF TEA SUPPLY FUNCTIONS

Eqn.	Intercept	P(T)	LT(-5)	WAGR	WMNF	DUM	D.W.	R^2
6.21a	15.37 (1.47)	.32 (1.31)	.16 (.21)	.61 (2.03)	-.31 (-2.14)	-.0002 (-.002)	2.41	.68
6.21b	11341700 (.52)	3658900 (1.15)	16.98 (.96)	14944700 (1.99)	-1897930 (-1.76)	-503447 (-.08)	2.51	.75

Figures in the parentheses are respective t-scores
a. indicates that the estimation was done in log-linear form
b. indicates that the estimation was done in linear form

Jute

Table 6.1 presents the estimated equations for the jute supply function. The explanatory power of some of the equations, given by the value of coefficient of determination, is quite high relative to the rest and the price of jute is statistically significant in all of them. Among the equations with higher explanatory power, namely, (6.26a), (6.31a), (6.26b), and (6.31b), it is very difficult to chose any one on the basis of theoretical arguments. We shall, therefore, use equation (6.31a) on an ad hoc basis and use the elasticity of supply implied by it, 0.69 in the next chapter. It may be mentioned that the elasticities of supply calculated from the linear estimates using the average values for the variables over the sample period range from 0.39 to 0.64 which is quite close to the corresponding estimates yielded by the log-linear versions. In addition, it is interesting to note that Mujeri's (1978) estimate of the supply elasticity of jute for Bangladesh, based on a linear specification of the supply function, was 0.69 which compares nicely with our own estimate, although we used a different set of variables and time period.

Rice

For rice, the estimated equations are presented in Table 6.2. As is seen there, the explanatory power of almost all equations, except number (6.38b), is very good and the price of rice has the proper sign in all of the equations. However, it is statistically significant in two equations only, namely, (6.36a) and (6.36b). The elasticities of supply implied by these equations are 0.18 and 0.17 respectively. In view of the higher explanatory power of the former, this shall be used by us as the rice supply function for Bangladesh. The estimates of the elasticity parameter for Bangladeshi rice done by others using different techniques and sample period are comparable with our estimate of 0.18. For example, Hussain (op. cit.) estimated the supply elasticity for rice for the period 1948-63 and found this to lie between 0.03 to 0.09. In other studies, Cummings (1974) used the data for the years 1949 to 1968 and found a value of 0.13 for the parameter while Askari and Cummings (1973) estimated this to be 0.23 over the period 1950 to 1968. The fact that these estimates are outdated was the main reason for rejecting them in this study and compute new estimates.

Sugarcane

The ten estimated equations for the sugarcane supply function appear in Table 6.3. As is seen there, the explanatory power of each of the equations is very good and the price of sugarcane has the proper sign and is statistically significant in all the equations except

(6.36a) and (6.36b). Again, we have no theoretical ground for selecting any of the equations in particular. We have decided to pick equation (6.33a) as the representative equation and the price elasticity of supply indicated by this equation is 0.31 which shall be used for further calculations. The price elasticities calculated from the linear versions of the equations range from 0.23 to 0.27 except that of equation (6.26b) where it assumes a value of only 0.12.

Tea

Unlike the three crops mentioned above, tea has only two estimating versions of the supply equation which are reported in Table 6.4. The perfomance of both the equations are quite satisfactory and the supply elasticities yielded by them are 0.32 and 0.31 respectively. The former represented by equation (6.21a) has been adopted for further use.

Elasticity of jute supply in the world market

Apart from the supply elasticities for individual crops, the present study also requires an estimate of the elasticity of supply of jute in the world market. Although several studies have been done concerning the role of jute in the world market, none of these have estimated an aggregate supply elasticity for jute taking the world as a whole.23 Due to the constraints of of time and space, we did not estimate the parameter ourselves. An alternative method was used to solve the problem. The study of Mujeri provides estimates of the supply elasticities of jute for India and Thailand while we have our own estimate of it for Bangladesh (which, incidentally, is identical with the corresponding estimate obtained by Mujeri). These three countries together produce over ninety per cent of the total jute production of the non-centrally planned economies.24 As most of the small producers of jute use it for internal consumption only, these three countries together virtually control the total supply of jute that enters into world trade. Thus we decided to take the average of the supply elasticities in these countries, weighted by their respective shares in production among themselves. It is important to note that Mujeri's estimates are not based on a constant elasticity framework, but, as no other estimates are available, we have decided to use his estimates on the assumption that these estimates will be the same as supply elasticities estimated in a constant elasticity specification.25,26 The supply elasticities for these countries and the shares of each country in total production in 1977 are presented in Table 6.5 below.

TABLE 6.5

ELASTICITIES OF JUTE SUPPLY

IN MAJOR PRODUCING COUNTRIES

AND THEIR SHARES IN OUTPUT IN 1977

		Elasticity s(J)j	Share zj
Bangladesh	(j=1)	.69[a]	.376[c]
India	(j=2)	.71[b]	.542[c]
Thailand	(j=3)	.82[b]	.082[c]

Source: a: Our estimate,Table 6.1; b: Mujeri (1978), p.148; c: F.A.O. Production Yearbook, 1978.

The elasticity of supply of jute in the world market, sW(J), is given by:

$$(6.39)\quad sW(J) = \sum_{j=1}^{3} zj\,s(J)j$$

Substituting the data from Table 6.5, we get a value of 0.712 for sW(J) which will be used here as the estimate of the world supply elasticity of jute.

VI.3 Estimation of the Remaining Parameters

VI.3.1 Introduction

In the last section we have presented estimates of the parameters of the supply function for the four crops under study. In this section, we present the estimates of the rest of the parameters. First of all, we estimate or select the parameters for the demand functions. Next, the parameters for the cost functions of AREA will be derived. The section concludes with the estimation or specification of all other parameters of the model not included above or in the previous section.

VI.3.2 Estimation of demand elasticities

Jute

A comprehensive econometric estimate of the Bangladeshi jute market is reported in Mujeri. We have decided to use the parameters of the jute demand function estimated by him for two reasons:

First, the sample period covered by Mujeri roughly coincides with our own period of study.

Second, Mujeri has computed both linear and log-linear estimates of the demand function: an approach we have used in estimating other relevant parameters.

Mujeri observed that the performance of the demand function in log-linear form was "decidedly better" and found the elasticity of demand to be -0.878.

Rice

There has been no recent study of the rice market in Bangladesh, so that the task for estimating the price elasticity of demand for rice was left to us. In the absence of any a priori knowledge on the forms of the utility function of the people of Bangladesh, the aggregate demand function for rice has been formulated on somewhat pragmatic grounds and is described below:

(6.40) QD(R) = QDR{P(R)**, P(S)**, INC**, POP}

where,

QD(R) : demand for rice by the total population of Bangladesh

P(R)** : price of rice in nominal terms

P(S)** : nominal price of a substitute commodity

INC** : nominal income of the Bangladeshi people

POP : total population of Bangladesh.

Each of these variables has previously been used by different economists as an argument of the rice demand function, and, for the sake of brevity, we refrain from any further discussion of them.

In equation (6.40), the price of rice appears on the right hand side implying that it is an independent variable in the demand function. This does not describe the true characteristics of the rice market in Bangladesh where, as we have already seen, the price is determined through the interaction of the forces of demand and supply. In order to incorporate this we have to replace equation (6.40) by the following system of equations:

(6.41) QD(R) = QDR{P(R)**, P(S)**, INC**, POP}

(6.42) QTR = QS(R) + QMR

(6.43) QD(R) = QTR

where,

QS(R) : domestic production of rice

QMR : amount of imported rice

QTR : total rice available in the country

Equation (6.42) describes the supply situation in the rice market in Bangladesh.27 Since QS(R) depends on lagged prices and QMR depends on non-economic factors, both of them are fixed for any given market period. Equation (6.43) is the market clearing condition. The reduced form of the above system is:

(6.44) P(R)** = PR**{QS(R), P(S)**, INC**, POP}

The above equation is theoretically a better estimating equation than equation (6.40) and will be used by us. From this the original demand function and its parameters can always be derived.

In empirical estimation, the major problem was the existence of high degree of collinearity between the price of rice and that of its substitute. To overcome this, we decided to drop the latter variable and deflate all remaining relevant magnitudes by an index of prices other than rice. This converted the nominal variables into real terms and the modified equation takes the following form:

(6.45) P(R) = PR{QS(R), INC, POP}

where the variables without asteriks represent real magnitudes.

We specified the above function in both linear and log-linear terms for the purpose of estimation. The technique of ordinary least squares was applied over the sample period 1965-77. The absence of reliable import figures prior to 1965 prevented us from using any larger sample period for study. The estimated equations in both log-linear and linear versions are reported in Table 6.6 below.

TABLE 6.6

ESTIMATES OF PRICE ELASTICITY OF DEMAND

FOR RICE IN BANGLADESH DURING 1965-1977

Eqn. No.	Intercept	QTR	INC	POP	D.W.c	R2
6.45a	86.92	-3.52	-1.65	-1.83	2.02	.61
	(2.54)	(-2.61)	(-2.13)	(-1.43)		
6.45b	4270.72	-0.18	-0.00005	-0.01	1.72	.53
	(2.42)	(-2.36)	(-1.93)	(-1.15)		

a: log-linear estimate; b: linear estimate;
c: Durbin-Watson Statistics
Figures in the parenthesis are respective t-scores

It appears that the log-linear version of the equation has slightly better explanatory power and is in no way inferior to the linear version. The price elasticity of demand for rice implied in the log-linear version is -0.28 which shall be used by us for subsequent analyses. This estimate compares favourably with that of Alamgir and Berlage (1973). Their study of the food market in Bangladesh covered the period 1950-69 and found the price elasticity of demand of local rice to be -0.29 and that for total foodgrains to be -0.28.

Sugar and Tea

Both these crops are produced in Bangladesh and traded in the world market. However, the share of Bangladesh in total world production of these commodities is very low and as such, the actions taken by Bangadesh is unlikely to influence the affairs of the world market.28 Thus according to the allocation model described in the last chapter, demand parameters for these crops are not required for the purpose of estimation of benefits.

Elasticity of jute demand in the world market

The final demand parameter needed for operating the model is the price elasticity of demand for jute in the world market. Unfortunately, as in the case of supply, we could not find any worldwide study of aggregate jute demand, and it was not possible for us to embark on such a study. Instead, from the studies of Khan (1972) and Mujeri, we were able to obtain price elasticities of demand for jute for five major consuming countries of the non-centrally planned economies. These are: Bangladesh, India, Thailand, the U.K., and the U.S.A. These countries together consume about seventy five per cent of the total jute production of the non-centrally planned economies. Since many small jute producing nations usually consume their total production domestically and do not enter into world trade, the share of these five countries in the consumption of the jute actually traded in the world market is much higher. The major problem in using these parameters is that some of them are not estimated in the framework of constant elasticity of demand. However, in the absence of any other information and considering the fact that the elasticities computed from the linear and log-linear versions were found to be very close in all the instances where such comparisons were possible, we are using these estimates in a constant elasticity framework.29 Table 6.7 presents these elasticity estimates for the five countries and also describes the share of each country in total consumption done by them in 1977.

TABLE 6.7

ELASTICITIES OF JUTE DEMAND

IN MAJOR CONSUMING COUNTRIES

AND THEIR SHARES IN CONSUMPTION IN 1977

		Elasticity {d(J)j}	Share {yj}
Bangladesh	(j=1)	-.8780[b]	.239
India	(j=2)	-.4400[b]	.690
Thailand	(j=3)	-.8938[a]	.028
U.K.	(j=4)	-.3063[a]	.032
U.S.A.	(j=5)	-.3442[a]	.011

Source: a: Khan (1972), p.89; b: Mujeri (1978), p.187
F.A.O. Production Yearbook, 1978; our estimate

The world price elasticity of demand {dW(J)} is given by:

$$(6.46) \quad dW(J) = \sum_{j=1}^{5} yjd(J)j$$

Substituting the values from Table 6.7, we get

$$dW(J) = -0.553$$

VI.3.3 Estimation of the parameters of the cost functions and the remaining parameters

Since our allocation model is cast in an ex ante framework, there is no way of getting any information on the costs of research and extension pertaining to Bangladesh. The ideal solution in this case is to use the data from a country which is similar to Bangladesh and where some research and extension has been done in the crops under study. In estimating the parameters of the cost functions, we shall follow this approach as closely as possible.

A. Parameters for research costs

Jute

Unfortunately, thus far little research has been done for jute. The closest crop to jute for which figures on research costs are available is cotton as the object of both jute and cotton research is to increase the fibre content of the plants. Ayer and Schuh have reported the total research costs undertaken in cotton cultivation techniques in the state of Sao Paulo , Brazil, and the resulting shift in the supply curve.30 We shall use their estimate to derive our research cost parameter for jute in Bangladesh which is reported in Table 6.8, along with the research cost parameters for the remaining crops.

Rice

Rice is one of the few crops that have attracted the attention of many countries in terms of research. Data on the costs of research, however, are available only for a few countries. Of these, Japan has similar factor endowments and is also climatically closer to Bangladesh. Hayami and Akino (op. cit.) have reported the costs for the Japanese rice breeding programme and the consequent shifts in the supply function. We have used their cost figures with two modifications to meet the special features of Bangladesh. These are:

(a) As we found in Chapter III, in Bangladesh the need exists for developing high yielding seeds for two disctinct varieties of rice, aus and aman. Assuming that the development of new seeds in each variety requires the same cost as in Japan, we have multiplied the latter by two to determine the total costs for rice research in Bangladesh.

(b) In 1978, total production of non-high yielding varieties of rice in Bangladesh was nearly seventy seven per cent of the total rice output.[31,32] This implies that a one per cent shift in the supply of the former rice variety will cause a 0.77 per cent shift in the latter's supply. Since our analysis is cast in terms of total rice production, it was necessary to convert the cost figures accordingly. This was accomplished by multiplying them by 1/0.77 or 1.299 to obtain the modified cost figures. On account of the modification, an 'h' per cent shift in the supply implied by the new cost function refers to the total supply of rice, which is actually realized through shifting the supply of non-high yielding rice varieties by 1.299h times.

Sugarcane

Although many countries of the world have undertaken research programmes in sugarcane, information on research costs in this crop was limited. Evenson and Kislev (1969) have reported research costs on sugarcane for several countries including the Caribbean countries, which have chosen to calculate the comparable cost figures for similar research in Bangladesh. The information provided by Evenson and Kislev had to be supplemented to get the effects of the research on the supply shift. This was done by comparing the yields from sugarcane in the Caribbean countries during the periods prior to and following the period of research. The data for respective yields were obtained from various issues of the F.A.O. Production Yearbook.

Tea

Like jute, tea is a crop in which little research has been done so far. Alvin (1976) has reported the research costs undertaken in Brazil for improvements in cocoa cultivation. Since both tea and cocoa are perennial crops and since no direct estimate of research costs in tea is available, we used Alvin's estimates to measure the research costs in Bangladeshi tea. As for the effects of the research on supply shift, methods identical to that used for sugarcane were employed.

The parameters of research cost gathered from the sources mentioned above and modified as necessary are presented in Table 6.8 below.

TABLE 6.8

PARAMETERS OF RESEARCH COST FUNCTIONS

(In Millions of 1978 U.S. Dollars)

Crop	Source Crop	Source Country	Cost for 1% shift
Jute	Cotton	Brazil	169.42
Rice	Rice	Japan	185.29
Sugarcane	Sugarcane	Caribbean countries	25.49
Tea	Cocoa	Brazil	67.77

Source: Reported in the text above

B. Parameters for extension costs

The task of gathering information on the costs of extension was more difficult than that of gathering the costs of research. Evenson and Kislev (1975) have provided some information on the costs of extension incurred by individual countries. But, unfortunately, they did not report costs separately for each crop, and as such, their information is of little use for the present study. On the other hand Ayer and Schuh have estimated the recurring annual costs for extension in cotton cultivation to be 1.5 per cent of total research cost in cotton development. In the absence of any other information, we shall use this figure as representative of the extension costs in all the four crops under study.

C. Other parameters

The parameters which have not been estimated so far are: b(J), 'r', 'p', and 'q' which represent the share of Bangladeshi jute in the world market, the rate of discount, and the lengths of research and benefit (hence, extension) periods respectively.33 From the recent issues of the F.A.O. Production Yearbook the value of b(J) was calculated to be 0.35. The selection of the appropriate rate of discount for project analysis has generated considerable controversy which is yet unsettled.34 For our study, we shall use the long term interest rate offered on term deposits in Bangladesh. This seems appropriate since the programme of AREA envisaged in the model is assumed to have a long lifetime. The current value of the long term interest rate in Bangladesh was computed by us and found to be fifteen per cent35. Since Bangladesh has some infra-structure established for crop research and since she can gainfully employ the experiences of other countries, the time taken for initiating a successful research programme should not be very long. Alvin has found that Brazil required approximately five years to derive benefit from an investment programme in cocoa research. The state of cocoa research in Brazil prior to this investment spell was comparable to the states of research in the crops under study in Bangladesh, namely, an organization with some researchers is there but with little headway due to lack of funds and sincere public sector support. As a result, five years appear to be an acceptable choice for the parameter 'p' in Bangladesh. Finally, it has been found that despite continued maintenance research, the yield advantage of the high yielding seed varieties begins to fall after a certain period. This suggest that there is a finite limit for the parameter 'q'. Looking at the data for high yielding crops in Bangladesh presented in Chapter III, we find that this limit is reached there in less than fifteen years. However, if proper attention is given to maintenance research, there is no reason for the yield decline to show up before fifteen years. Consequently, a value of fifteen years was specified for 'q' to be used in the model. It should be pointed out that even if the yield begins to decline after fifteen years, the superiority of the high yielding varieties over the local ones will persist for a few years beyond that period due to the fact that the costs of extension are relatively low and the yield advantage is not likely to disappear instantaneously. As a result, the measurement of net benefits from AREA using a value of fifteen years for 'q' will provide a conservative estimate for it, despite the assumption of instantaneous adoption of the new technology by the farming community.

VI.4 Summary of the Chapter

The present chapter, which has been fairly long and diverse in content, has one common theme throughout: to develop parameters that are necessary to implement the model for investing funds in AREA outlined in Chapter V. We have been able to provide our own estimates for most of the parameters, based on best available statistics. The few remaining parameters which could not be estimated by us were obtained from reliable econometric studies done by others. The most important thing to note is that we did not have to specify ad hoc values for any of the parameters. The major problem faced in this chapter was the non-availability of any data on the costs of research in jute or tea. This was solved by selecting the research cost figures for crops which are very close to the above two in various respects. Like the other parameters, the cost figures presented in this chapter are the best possible ones available at present. Any rational plan for allocating funds to AREA must begin with some benchmark data for everything. As research proceeds and new information start to flow in, the conclusions arrived at the outset should be re-examined and if necessary, modified, a feature which is common to most planning problems.

With the model specified and all of its parameters estimated, the next job in the sequence is to implement the model with the help of the parameters and other equilibrium values. This major task, the last component of our study, is the subject matter of the forthcoming chapter.

FOOTNOTES TO CHAPTER VI

1. Tea is a traditional export crop for Bangladesh. Sugar is exported during the years of good harvest and imported when there is a shortfall. In any case, the domestic price of both the crops is determined in the international market.

2. See Chapter III for a description of cropping seasons for these crops in Bangladesh.

3. See, for example, Hussain (1964), Mujeri (1978), Ahmed (1978).

4. Ahmed (1974) and Ahmed (1978) have provided some estimates of agricultural capital stock in Bangladesh. However, these are measured aggregatively and there is no way of breaking them up cropwise. It may be mentioned that much agricultural capital, particularly traditional tools and bullocks, is not crop specific so that it is allocated across crops in as much the same way as land. We can, therefore, assume that such capital is used in fixed proportions to land especially in the short run.

5. The symbol "Qi" has been used here to represent the production function for crop i.

6. It should be noted that random variables such as flood and drought, do not enter into the land demand function. These variables affect output after land allocation is done and, hence, are introduced directly into the supply functions discussed below.

7. For a detailed discussion and bibliography, see Askari and Cummings (1976).

8. Although there has been no attempt to estimate the agricultural production function per se for Bangladesh, Ullah (1974) and Ahmed (1978) have provided indirect support to the view that agricultural production functions in Bangladesh possess the properties of a neo-classical production function.

9. The use of desired output in place of desired acreage in agriculture (specially, in a Nerlovian framework) is not very common. See Askari and Cummings (1976), pp.30-31.

10. Our knowledge of various aspects of tea production has been enriched by Dayananda (1977).

11. See Bateman (1965,1968), Tweeten and Quance (1969), Rajagopalan and Meenakshisundaram (1969), Rajagopalan et al. (1971) and Dayananda (1977) for detailed analyses on various aspects of the problem.

12. Nerlove quotes the following formulation of the elasticity of expectations: it is "the ratio of the proportional rise in the expected future prices of (commodity) X to the proportional rise in its current prices". The quotation appears in Hicks (1946), p.205.

13. In this formulation, we have to impose some constraints accross the parameters a(3) and a(5) and across a(4) and a(6) to get consistent estimates. This suggests the use of non-linear least squares as the estimating technique. However, ordinary least squares will still provide consistent estimates of the coefficients of price variables.

14. Fortunately, this problem becomes important in the context of estimating the lag parameters, not in the estimation of the short run elasticity of supply.

15. In addition, if all the relevant variables were included, we will have too many independent variables. This might create a shortage of degrees of freedom given that our sample size is not very large.

16. Some economists have attempted to introduce the weather variable by specifying an expectation function for it similar to that of price expectations. See Parikh (1971) for a discussion of these.

17. Obviously, in this formulation, each year will show up either as a flood year or as a drought year, unless the average rainfall of any particular year coincides with the sample period average. An alternative approach may be to specify a range of normal rainfall and construct the indices in the same way. This was also tried, but with no perceptible effect on the results described in the text.

18. As already mentioned in Chapter III, the general econometric concepts used in this study can be found in Johnston (1972).

19. An excellent review of the lagged models is provided in Griliches (1967), see also Kmenta (1971).

20. See Griliches (1967), pp. 35-47.

21. See Johnston (1972), pp.296-300.

22. Malinvaud (1966), p.491.

23. Some of these studies are: Rabbani (1964), Khan (1972), Mujeri (1978).

24. The reason for excluding the centrally planned economies from our study is the non-availability of adequate data on them.

25. It should be mentioned that in our own estimates, where both log-linear and linear versions were tried, the divergence between these two estimates in terms of the elasticity parameter was found to be quite low.

26. Measuring the world elasticity as a weighted average of constant supply elasticities of individual countries implies either or both of the following: (a) individual supply elasticities for each country are equal, (b) the shares of these countries in total production are constant. This is proved below.

Let us assume that there are two countries, A and B, the supply function for each being given by:

(6.47) $QS(A) = G(A)PW^{s(A)}$

(6.48) $QS(B) = G(B)PW^{s(B)}$

where the definitions of the variables are similar to those used in Chapter V with the countries replacing the crops inside the parentheses. The total world supply is given by:

(6.49) $QSW = QS(A) + QS(B)$

Substituting equations (6.47)and (6.48) into equation (6.49) and applying the formula for elasticity of supply, we get

(6.50) $s(W) = s(A)\{QS(A)/QSW\} + s(B)\{QS(B)/QSW\}$

From equation (6.50) it follows that s(W) is constant only if either (a) s(A) = s(B) or (b) {QS(A)/QSW} and {QS(B)/QSW} are constant. This can easily be generalized for more than two countries. In our study we find that the elasticities of supply for the three countries under study are very close which satisfies the first condition above.

27. Incidentally, the fact that Bangladesh imports some rice does not violate our assumption that its price is determined domestically. The ratio of imported rice to total rice consumption in the country is small and, during the years of good harvest, virtually disappears. Moreover, rice is imported by the government and usually sold at subsidized prices. As a result, the quantity of imported rice can be considered exogenous.

28. The share of Bangladesh in the world sugar market is less than one per cent while that in the world tea market is approximately three per cent.

29. By following the steps outlined in Footnote 26 above, it can be proved that the conditions for world demand elasiticity to be constant when it is measured by taking the weighted average of constant demand elasticities of individual countries are: either (a) individual demand elasticities are equal, or (b) the share of each country in total consumption is constant. While the first condition is not strictly true, available data lend support to the second contention.

30. In Chapter V we observed that Ramalho de Castro (1974) has claimed that the potential for achieving technical change in the agricultural sector of Brazil is very high. There is no contradiction between his claim and the current observation of technical change in Brazillian agriculture. The crops that Ramalho de Castro had in mind do not include the cotton of Sao Paulo and cocoa (see below for its relevance).

31. The year 1978 has been used in the study as the base year for projection. The reasons for this are explained in Chapter VII.

32. See Statistical Yearbook of Bangladesh, 1978, p.167. The figures quoted there had to be adjusted for following reasons. The total amount of local rice varieties produced is shown there to be 10,830 million tons, which does not match the values for its components. Obviously, it was a misprint and the correct value should be 9,830 million tons. The Yearbook also presents a total rice production figure of 12.765 million tons which differs slightly from another value, 12.764 million tons, published on page 166, which we used in our study.

33. The remaining elements for which no value has been specified in this chapter are FARE and h(i)U. Strictly speaking, these are not parameters and we have specified alternative values for them in the next chapter as parts of our experiment with the model.

34. See Layard (1974) for detailed analysis of the subject of rate of discount. For a recent discussion see Smith (1979).

35. We could not find any published report concerning the value of long term rate of interest in Bangladesh. The parameter was computed in the following way. From newspaper advertisements we found that the face value of a long term bond in Bangladesh doubles in six years. An equation was formulated on the basis of this information, the solution of which yielded a value of approximately fifteen per cent for the rate of interest.

CHAPTER VII

EMPIRICAL APPLICATION OF THE ALLOCATION MODEL

VII.1 Introduction

The primary purpose of this chapter is to analyse various consequences of the allocation of research and extension funds to the four crops under study, namely, jute, rice, sugarcane, and tea, in the context of Bangladesh. We have already seen that these four crops constitute more than ninety per cent of the cropped area of Bangladesh and that they are exchanged under different market conditions which will force us to use all three types of the benefit functions stipulated in Chapter V. The application of the model is based on the estimates of the parameters presented in the previous chapter and on some equilibrium values of prices and quantities. This chapter is divided into seven sections. A brief review of the parameters and their estimated values is presented in Section VII.2. Section VII.3 selects the equilibrium values for the four crops while the next section defines several alternative choices of the parameters for the purpose of various experiments. Sections VII.5 and VII.6 are devoted to the reporting and analysis of the empirical results. The chapter (and also the thesis) concludes in Section VII.7 with a general summary of the entire study and a description of the possible ways in which this work can be modified and/or extended.

VII.2 Brief Review of the Parameters

In the last chapter, we utilized different estimating techniques to get numerical values for all the parameters needed to operate our allocation model in the context of Bangladesh. These parametric values appear scattered throughout that chapter. The purpose of the present section is to present them in a consolidated form so that they can be found and used with ease. This is done in Tables 7.1 to 7.4 below.

TABLE 7.1

PARAMETERS OF THE SUPPLY FUNCTIONS

Crop {i}	Elasticity of supply in the home market {s(i)}	Elasticity of supply in the world market {sW(i)}
Jute	0.69	0.712
Rice	0.18	not required
Sugarcane	0.31	not required
Tea	0.32	not required

TABLE 7.2

PARAMETERS OF THE DEMAND FUNCTIONS

Crop {i}	Elasticity of demand in the home market -{d(i)}	Elasticity of demand in the world market -{dW(i)}
Jute	-0.88	-0.553
Rice	-0.28	not required
Sugarcane	infinity	not required
Tea	infinity	not required

TABLE 7.3

PARAMETERS OF THE COST FUNCTIONS

Crop {i}	Research cost Coefficients {v(i)}	Extension cost Coefficients {e(i)}	Total cost Coefficients {w(i)}
Jute	U.S.$169.42m	0.015	U.S.$177.91m
Rice	U.S.$185.29m	0.015	U.S.$194.59m
Sugarcane	U.S. $25.49m	0.015	U.S. $26.77m
Tea	U.S. $67.77m	0.015	U.S. $71.17m

TABLE 7.4

OTHER PARAMETERS

Name	Symbol	Value
Share of Bangladeshi jute in world market	{b(J)}	0.35
Length of research period	{p(i)}a	5 years
Length of benefit period	{q(i)}a	15 years
Rate of discount	{r}	0.15

a: These values are assumed identical for all four crops.

VII.3 Selection of Equilibrium Values for Prices and Quantities

Since we have assumed that it will take five years for a research programme to be completed and that the benefits coupled with the extension costs will continue for the next fifteen years, there is no way of getting the exact values of the prices and quantities relevant for computing the benefits. This is because of the fact that the ideal values for them are those prevailing for the fifteen consecutive years beginning five years from now (assuming that the research projects starts immediately), none of which can be obtained beforehand. It is, however, possible to resolve the problem in two ways. First, we can project the future values for these variables. Alternatively, we can use the values available for the most recent year and use them for the future years as well. In the absence of comprehensive econometric models as a basis for reliable forecasts, we shall fall back on the second method which, essentially, is a naive form of projection.1

We have taken the year 1978 as the base year from which various equilibrium values have been selected. The reasons for using the year 1978 are explained below. First, this is the most recent year for which a complete set of data was available for all the variables needed in our study. Second, the year 1978 can be viewed as a normal year both for Bangladesh and for the world as a whole. Internally, this year as well as several preceding years were free from any major natural calamities such as flood, drought, and/or cyclone. Bangladesh was politically more stable than ever before in 1978; with the new government, which came into power in November, 1975, having gained considerable experience and strength. There were no major economic dislocations such as currency devaluation or labour strife. Externally, major economic or political disruption such as an intensification of the energy crisis or the escalation or eruption of a war happened less frequently in 1978, as compared with other years. As a result, the year 1978 can be regarded as free from the influences of any major disturbances. Finally, 1978 is only one year past the data period used to estimate most of the parameters and as such, these parameters retain their relevance and usefulness in 1978. The specific equilibrium values selected for the study are presented in Tables 7.5 and 7.6 below.

TABLE 7.5

EQUILIBRIUM VALUES FOR

DOMESTIC PRODUCTION AND EXCHANGE

Crop {i}	Domestic Production {QS(i)}	Prices {P(i)=PW(i)}
Jute	0.977m tons	$137.67 per ton(a)
Rice	12.764m tons	$283.95 per ton(a,c)
Sugarcane	6.590m tons	$18.95 per ton(a)
Tea	0.036m tons	$1,240.32 per ton(b)

Source: Statistical Yearbook of Bangladesh, Various issues, especially, 1978.
a: harvest price received by the farmers;
b: auction price at Chittagong, the major area of concentration of tea production and trade.
c: weighted average of prices of different rice varieties.

It should be noted that all the prices were converted into U.S. dollars (1978) by using a currency conversion rate of Taka 15.08 for each U.S. dollar, where the Taka is the unit of Bangladesh currency.2 The prices received by the producers have been selected instead of other price measures. The reason for using the producers' prices is that it is at the producers' level where the primary effects of technical change appear. The use of any other price series will incorporate the influences of other services such as marketing and retailing. In the cases where a measure of world prices is required, domestic prices have been used with the assumption that they are determined in the world market. The other equilibrium values needed for the study, apart from those on domestic production and prices, are presented in Table 7.6.

TABLE 7.6

OTHER EQUILIBRIUM VALUES

Name	Symbol	Value
Quantity of jute consumed domestically	{QD(J)}	0.509m tons
Quantity of jute exported abroad	not used	0.468m tons

Source: F.A.O. Commodity Review and Outlook, 1977-78; Statistical Yearbook of Bangladesh, 1978.[3]

VII.4 Description of Alternative Experiments

It is possible for a planner to carry out various experiments with the model specified in Chapter V. In this section we shall consider some of the major experiments. These experiments are based on the stipulation of different values for some of the parameters of the model. These parameters are FARE and h(i)U which represent the funds available for research and extension programmes and the physical upper limit to the shift parameter, respectively. The first one describes alternative decision frameworks open to the planner. Although the second parameter above, h(i)U, is, strictly speaking, a single number for each crop, it can be assigned smaller values depending on the ambitiousness of the project. For example, even if it is physically possible to raise the yield of any crop in Bangladesh by, say, eighty per cent, the planner might be interested to plan for a modest target of say, thirty per cent.4 Alternative parametizations of the shift parameter will also provide a sensitivity analysis of the model.

In this study, we have considered two alternative values for each of the above parameters, thus generating a total of four experiments, which are described below.

A. Alternative assumptions on FARE

The two alternatives considered by us on the availability of funds are denoted by FARE 1 and FARE 2 and they assume the following values.

(a) FARE 1 = infinity

(b) FARE 2 = $554.54 millions

In the first case it is assumed that there is no constraint on the availability of funds. This constitutes an extreme value for this element and will help us in determining the optimum or effective values for the shift parameter which will maximize total net benefits from investments in AREA for each crop separately, assuming no limit on investment funds. The second case allows for a finite limit to the availability of investment funds which is the common case for most of the developing countries. It will enable us to determine the tradeoffs between investment in the four crops. We have specified a value of $554.54 millions on the basis of the following reasoning. The total amount of funds allocated for development activities in agriculture, which includes AREA, was $115.56 millions in 1978.[5] It has already been mentioned that the present study assumes a total life of twenty years for any programme of AREA (five years for the research and the rest for extension and reaping benefits). Assuming that the same amount of funds will be available throughout this period, the discounted present value of the sum is $831.81 millions. Now, although the four crops under study accounted for nearly eighty three per cent of the total cultivable land in Bangladesh in 1978, we have assumed that only two-thirds of the above sum will be spent on them. Consequently, the value for FARE 2 becomes $554.54 millions.

B. Alternative assumptions on h(i)U

This is one of the important parameters of the allocation model which has been specifically set aside for a sensitivity test. In the absence of any restrictions, the optimum values of the shift parameters, h*(i), obtained by solving the model may be physically unattainable. It is, therefore, necessary to introduce some boundary values.

For each crop, we have specified two sets of upper physical limits. The first one is based on the assumption that modest success is achievable by Bangladesh through AREA and is denoted by UPL 1. Obviously, UPL 1 is a vector of four elements which will be represented by h(i)U1. The other specification of the upper physical limit assumes greater success for such programmes and is denoted by UPL 2. This is also a vector of four elements which are symbolized by h(i)U2. For each crop, the yield gap between that of Bangladesh and the Asian or the Far Eastern countries expressed as an average is considered to be a modest target for Bangladesh and is used to determine UPL 1. The only exception to the above procedure is the case of jute, for which the physical limit based on UPL 1 is taken from experimental data reported by the F.A.O. (1975). In selecting the physical limit under UPL 2 for jute, data are taken from a different experimental study reported in the same source. For rice, UPL 2 is specified from the yield advantages actually achieved in Bangladesh from research and extension activities in the winter rice crop known as boro. For the remaining crops, the differences in yields between those of Bangladesh and those of the U.S.A. or Japan are taken to determine UPL 2. It should be mentioned that for rice, these limits have been adjusted to take account of the fact that only seventy seven per cent of total rice output has the potential for technical change according to our assumption. The process of such adjustment is similar to that described in Chapter VI (Subsection VI.3.3). The physical limits formulated according to the methods described above are presented in Table 7.7.

TABLE 7.7

PHYSICAL LIMITS TO THE SHIFT PARAMETER

Crop	UPL 1	UPL 2
Jute	0.130	1.000
Rice	0.086	1.685
Sugarcane	0.120	0.820
Tea	0.400	1.180

Source: F.A.O. (1975); Various issues of Bangladesh Agriculture in Statistics and F.A.O. Production Yearbook; and our estimate.

On the basis of the different assumptions outlined above, we can formulate several experiments. These experiments are generated from combinations of the various possible alternatives and are described in Table 7.8.

TABLE 7.8

DESCRIPTION OF THE EXPERIMENTS

Name	Features
Experiment 1	FARE 1, UPL 1
Experiment 2	FARE 1, UPL 2
Experiment 3	FARE 2, UPL 1
Experiment 4	FARE 2, UPL 2

Having gathered all the relevant information on the allocation model and having specified various experiments that can be analysed, we can now investigate the allocation implications implied by the various experiments.

VII.5 The Results

In this section we plan to report the results of various experiments carried out under alternative specifications described in the last section. As mentioned in Chapter V, a lower limit of zero is specified for the shift parameter for all crops. The results have been arranged in terms of experiments rather that crops, and for the sake of brevity, the details of the computations have not been reported, unless it was felt necessary. Finally, it should be mentioned that the benefits and costs are calculated for the entire length of the programme (e.g., TB(i), TC(i))), not for any single year (e.g. AB(i)).

Experiment 1

Jute : For jute the optimum value of the shift parameter {h*(J)} when there is no constraint on the availability of funds is 0.944. However, this violates the other assumption of the experiment as h(J)L < 0.944 >h(J)U1. Consequently, the effective value for h(J), h'(J), is determined at the boundary and we have

h'(J) = hJ(U)1 = 0.130

Rice : The optimum value for h(R) in this case is 2.539 which also violates the premises of the experiment as h(R)L < 2.539 > h(R)U1. We, therefore, have

h'(R) = h(R)U1 = 0.086

Sugarcane : As {dTB(SC)/dh(SC)} > {dTC(SC)/dh(SC)}, for h(SC) = 0, the optimum value for h(SC) in this case is infinity as mentioned in equation (5.43) of Chapter V. As before, h(SC)L < infinity > h(SC)U1, which implies

h'(SC) = h(SC)U1 = 0.120

Tea : Tea also satisfies the condition {dTB(T)/dh(T)} > {dTC(T)/dh(T)} for h(T) = 0, and we have

$h'(T) = h(T)U1 = 0.400$

The effects of these values of the shift parameters on various magnitudes of benefits and costs are presented in Tables 7.9 and 7.10.

TABLE 7.9

ANALYSIS OF BENEFITS UNDER EXPERIMENT 1

(In Millions of U.S. Dollars)

Crop	Changes in Consumers Surplus	Changes in Producers Surplus	Changes in Total Surplus
Jute	16.97	35.53	55.50
Rice	295.66	-180.40	115.26
Sugarcane	Nil	38.25	38.25
Tea	Nil	45.58	45.58

Note: Figures may not add up due to rounding.

TABLE 7.10

ANALYSIS OF COSTS UNDER EXPERIMENT 1

(In Millions of U.S. Dollars)

Crop	Costs of Research	Costs of Extension	Total Costs
Jute	22.02	1.10	23.13
Rice	15.94	0.80	16.73
Sugarcane	3.06	0.15	3.21
Tea	27.11	1.36	28.47

Note: Figures may not add up due to rounding.

From a careful study of Tables 7.9 and 7.10 it is possible to derive some interesting conclusions regarding the effects of technical change in the crops under study. These conclusions, described below, are however contingent upon the specific assumptions of the experiment.

(a) All the four crops exhibit positive net benefits when AREA funds are spent on them. The net profitability of each crop depends on the parameters of its own benefit and cost functions only and is independent of any other assumptions of the experiments. As such, this basic result will not change in the subsequent experiments where variations of the physical limits and AREA funds are likely to change priority considerations among the crops.

(b) The target for supply shifts in each crop coincides with the respective upper physical limit which can be attributed to the modest assumptions on such limits.

(c) Total AREA cost for all the crops taken together is only $71.53 millions which is quite low in comparison to total investments in agricultural development programmes currently made in Bangladesh. This also underscores the fact that the upper physical limits specified in UPL 1 are quite low.

(d) The appearance of negative changes in producers surplus in rice production is highly significant and calls for the adoption of appropriate public sector policies to offset the loss.6 Otherwise, if the farmers stand to lose from the new technology, they might soon refuse to adop it. However, it should be pointed out that this conclusion is tentative and could be reversed if the gains to the producers as consumers outweigh the loss.

Experiment 2

Since the assumption on the availability of funds remains the same as before, the optimum values for the shift parameter {h*(i)} will be the same as those of Experiment 1.

However, the change in the assumptions on the upper physical limits will generate new values for effective shift parameters {h'(i)}. These are described below for each crop:

Jute : We have, $h(J)L < h^*(J) = 0.944 < h(J)U2$. The effective value of h(J) is, therefore, given by:

$h'(J) = h^*(J) = 0.944$

That is, in the case of jute under Experiment 2, the optimum and the effective values of the shift parameter are identical.

Rice : The situtation for rice is different from that for jute as in this case we have $h(R)L < h^*(R) = 2.539 > h(R)U2$. Therefore,

$h'(R) = h(R)U2 = 1.685$

Sugarcane : In the case of sugarcane, $h(SC)L < h^*(SC) = \text{infinity} > h(SC)U2$. As such, we have

$h'(SC) = h(SC)U2 = 0.820$

Tea : For tea, as in sugarcane, we have $h(T)L < h^*(T) = \text{infinity} > h(T)U2$, which means that

$h'(T) = h(T)U2 = 1.180$

The effects of these new values of the shift parameters on respective measurements of benefits and costs are described in Tables 7.11 and 7.12.

TABLE 7.11

ANALYSIS OF BENEFITS UNDER EXPERIMENT 2

(In Millions of U.S. Dollars)

Crop	Changes in Consumers Surplus	Changes in Producers Surplus	Changes in Total Surplus
Jute	107.66	179.56	287.23
Rice	6,420.60	-3,917.65	2,502.94
Sugarcane	Nil	261.34	261.34
Tea	Nil	134.47	134.47

Note: Figures may not add up due to rounding.

TABLE 7.12

ANALYSIS OF COSTS UNDER EXPERIMENT 2

(In Millions of U.S. Dollars)

Crop	Costs of Research	Costs of Extension	Total Costs
Jute	159.93	8.02	167.95
Rice	312.22	15.66	327.88
Sugarcane	20.90	1.05	21.95
Tea	79.97	4.01	83.98

Note: Figures may not add up due to rounding.

As is seen in the last two tables, the change of assumptions has altered some of the conclusions derived from Experiment 1. The new results are summarized below.

(a) The target for jute falls short of the upper physical limit set for it. The gap, however, is not very large and the rest of the crops are at their new levels of upper limits.

(b) The total AREA cost for the four crops taken together amount to $601.76 millions. This exceeds the limit of $554.54 millions specified under FARE 2. As FARE 2 will be imposed in Experiments 3 and 4, we can expect the resource constraint to be binding in Experiment 4. This will, in turn, produce a ranking of crops. In this study the ranking is determined by the net profitablity or benefits.

(c) The negative change in producers surplus for rice still persists and has increased in absolute amount.

In Experiments 3 and 4 the assumption of an unlimited supply of funds has been replaced by that of a finite supply. The methods of computations in these cases are, as was seen in Chapter V, more complicated than in the unconstrained cases. As a result, apart from reporting the optimum and effective values for the shift parameter, we shall include some discussion of the methods of the computation in describing the results.

Experiment 3

As mentioned in Chapter V, before solving the allocation problem with constrained funds we have to arrange the crops in descending orders of 'N' or 'M' values, where N = $\{dTB(g)/dh(g)-dTC(g)/dh(g)\}$ at $h(g) = 0$, and applies to crops with non-linear benefit functions and M = $dTB(j)/dh(j)-dTC(j)/dh(j)$ which refers to the crops with linear benefit functions.

Table 7.13 below describes these 'N' and 'M' values for the four crops under study.

TABLE 7.13

DESCRIPTION OF THE 'N' AND 'M' VALUES

(In Millions of U.S. Dollars)

Crop	N(g)	M(j)
Jute	247.88	Not applicable
Rice	4,784.47	Not applicable
Sugarcane	Not applicable	291.94
Tea	Not applicable	42.79

From Table 7.13 we find that N(R) > N(J) and that M(SC) > M(T). We also have N(R) > M(SC) > N(J) > M(T). By equation (5.54) of Chapter V, we have M*(1) = M(SC) = 291.94. Solving dTB(R)/dh(R) - dTC(R)/dh(R) = M(SC), we get h*''(R) = 1.476. Since this value exceeds both h(R)L and h(R)U1, we have

h'(R) = h(R)U1 = 0.086

Now, CERE = h'(R)w(R). Comparing this with FARE, we find that FLFA = FARE - CERE is greater than zero. This implies that the next crop, sugarcane, should come into consideration. Allocating the whole of FLFA to sugarcane, we find $h^*(SC) = 20.094$. This also exceeds the upper physical limit specified for the crop. As such, we have

$h'(SC) = h(SC)U1 = 0.120$

Computing FLFA afresh, we find that it is still positive. Since $h^{*''}(R)$ was greater than $h(R)U1$, we do not have to consider rice again in conjunction with jute (since $N(J) > M(T)$, jute is the next crop to be considered), as the former has already reached its physical limit. Turning to jute we solve $dTB(J) - dTC(J) = M(T)$ and obtain $h^{*''}(J) = 0.773$. As before, we find this value to be in excess of the upper physical limit. Thus we have $h'(J) = 0.130$. FLFA is positive once again, which means that tea is included for consideration. By allocating the remaining funds to tea, we get $h^*(T) = 7.232$. Since the upper physical limit for tea is lower than this, the effective value of $h(T)$ is given by, $h'(T) = 0.400$.

It should be noted that the allocations specified above fail to exhaust the funds for investment. However, as all crops have reached their physical limit, there is no point in investing the funds into these crops any further. We observe that the values of $h'(i)$ for each crop under Experiment 3 are the same as those under Experiment 1. As a result, the effects of this experiment on different measures of benefits and costs will be identical to those presented in Tables 7.9 and 7.10. It should pointed out that athough the quantitative results are the same as in Experiment 1, Experiment 3 is qualitatively and methodologically different from the former. The assumption of a perfectly elastic supply of AREA funds was dropped in this experiment. This called for an establishment of priorities among the crops. The ranking that emerged from Experiment 3 is: rice, sugarcane, jute, and tea in descending order. We find that rice commands priority by virtue of its sheer size. However, despite the fact that jute outweighs sugarcane in terms of acreage and value, sugarcane dominates jute in actual allocations as the cost of research and extension programmes in sugarcane is much lower compared to the cost for jute.

Experiment 4

As explained in the previous experiment, the solution of $dTB(R)/dh(R) - dTC(R)/dh(R) = M(SC)$ yields $h^{*''}(R) = 1.476$. But in contrast to Experiment 3, we now have $h(R)U2 > h^{*''}(R) = 1.476$. This gives $h''(R) = h^{*''}(R) = 1.476$. Since FLFA > 0, the next crop, sugarcane, is considered. By applying the remaining funds to sugarcane a value of $h^{*}(SC) = 9.988$ is reached. As this exceeds the upper physical limit specified for sugarcane, we get $h'(SC) = h(SC)U2 = 0.820$. The FLFA is computed as before and is found to be positive which brings jute into consideration. However, in this case we have $h^{*''}(R) < h(R)U2$, so rice now competes with jute for investment funds. Solving $dTB(R)/dh(R) - dTC(R)/dh(R) = M(T)$ and $dTB(J)/dh(J) - dTC(J)/dh(J) = M(T)$, we get $h^{*''}(R) = 2.108$ and $h^{*''}(J) = 0.773$. While the value of $h^{*''}(J)$ satisfies the assumptions of Experiment 4, the values of $h^{*''}(R)$ exceeds the upper physical limit for it. We, therefore, have $h'(R) = h(R)U2 = 1.685$ and $h''(J) = 0.773$. Now, as FLFA $> h'(R)w(R) + h''(J)w(J)$, there is no need to consider rice and jute in a simultaneous system and tea automatically gets included for subsequent allocations. By allocating the remaining funds to this crop we find $h^{*}(T) = 1.036$. As this value lies between the lower and upper physical limits specified for the crop, $h'(T) = h^{*}(T) = 1.036$. Since this allocation exhausts all the funds implied by FARE 2, we do not have to bring jute in for another round of consideration. Different measures of benefits and costs associated with the effective values of the shift parameter under this experiment are described in Tables 7.14 and 7.15.

TABLE 7.14

ANALYSIS OF BENEFITS UNDER EXPERIMENT 4

(in Millions of U.S. Dollars)

Crop	Changes in Consumers Surplus	Changes in Producers Surplus	Changes in Total surplus
Jute	90.50	157.66	248.16
Rice	6,420.60	-3,917.65	2,502.94
Sugarcane	Nil	261.34	261.34
Tea	Nil	118,06	118.06

Note: Figures may not add up due to rounding.

TABLE 7.15

ANALYSIS OF COSTS UNDER EXPERIMENT 4

(In Millions of U.S. Dollars)

Crop	Costs of Research	Costs of Extension	Total Costs
Jute	130.96	6.57	137.53
Rice	312.22	15.66	327.88
Sugarcane	20.90	1.05	21.95
Tea	70.21	3.52	73.73

Note: Figures may not add up due to rounding.

From the results reported in Tables 7.14 and 7.15 several relevant implications stand out. These are:

(a) Even though the ranking of the crops is essentially the same as that in Experiment 3, it is now achieved through a complicated and elaborate process. Strictly speaking, the ranking now is rice, sugarcane, rice, jute, and tea. This implies that rice should be reconsidered for AREA funds following sugarcane before any money can be diverted toward jute.

(b) Compared to Experiment 2, the targets set for jute and tea are now lower which means that these crops should get less AREA funds than specified under Experiment 2. The targets, and hence the allocation of funds, for rice and sugarcane are the same as in Experiment 2.

(c) Considered as a whole, AREA funds are scarce in supply. This implies that the marginal net benefits per dollar of additional AREA fund is equal to the rate of profit achievable from tea. The value for this can be obtained from the ratio M(T)/w(T) or \$42.79/\$71.17 which approximately equals 0.60. This rate will be effective until the upper physical limit for tea is reached, after which it will gradually diminish as allocations are redirected to jute and rice.

(d) Finally, the negative change in producers surplus for rice continues to exist.

VII.6 Overall Analysis of the Results

Based on the experiments described above, it is possible to derive some general conclusions which are summarized in the following discussion.

(a) It will be profitable to invest in research and extension programmes in each of the four crops under study, namely, jute, rice, sugarcane, and tea.

(b) The return to investment in such programmes is the largest for rice, followed by sugarcane, jute, and tea in descending order.

(c) The upper physical limit to the shift parameters, based mainly on the yield gap that exists between Bangladesh and the Asian or the Far Eastern countries is a very modest target and can be achieved with little investment in AREA. This is not surprising as most of these countries did not invest much in AREA in the past.

(d) On the other hand, the upper physical limit set in an ambitious outlook (by taking the yield differences between Bangladesh and the U.S.A. or Japan) is difficult to achieve. All of the investment funds earmarked for research and extension works in the four crops under a generous assumption, are exhausted before jute and tea reach the respective upper limit, or the point where margninal net benefits are zero.

(e) The most interesting finding of the study is that the rice producers will lose if they adopt the new technology. This reinforces our earlier claim that the public sector should come forward to sponsor AREA. As it appears, they will have to offer some incentives to the farmers, apart from supplying the technology, so that the latter may adopt it. This conclusion, however, is partial because the loss will be compensated to some extent as the producers benefit as the consuming class.

(f) We also find that the costs of AREA play an important role in the process of fund allocation. This is evident from the fact that even if the investment fund is unlimited, it is not profitable to invest in some crops up to the point where it reaches the maximum supply shift (example: jute in Experiment 2.).

(g) The findings of the chapter also provide empirical support to the general observations made by Binswanger (1978) that usually the crop with the greater share in agricultural output will dominate the others but that this may be reversed when costs of research are brought into consideration.7 In our study we have observed that the largest crop, rice, also commands priority over all others. But although jute is next to rice considering the acreage and the value of production, sugarcane dominates it by virtue of its low research and extension costs.

VII.7 Summary and Suggestions for Further Research

In the previous section we have outlined several important results derivable from our study. We hope that these results will prove useful to the planners of Bangladesh. This also marks the end of our present study concerning technical change in the agricultural sector with special reference to Bangladeshi agriculture. At this point, it may be worthwhile to present a brief summary of the study. In Chapter I we demonstrated the importance of agricultural growth in the context of overall economic progress. Chapter II revealed that the development of any sector is usually materialized through technical change which is often shaped by the interplay of the internal forces. A detailed discussion of the elements regulating induced technical change in agriculture was presented in Chapter III, which also examined the current state of Bangladeshi agriculture in the light of this newly acquired knowledge. The main purpose of Chapter IV was to provide rationale for the public sector to come forward to sponsor research and extension programmes in agriculture. Chapter V developed a formal model to help the public sector in fulfilling its role as the sponsor of such programmes. The parameters needed for implementing the model in Bangladesh were estimated in Chapter VI by utilizing different estimating techniques. Finally, the current chapter presented the major findings of the study.

For a researcher interested in this area, there is ample room for further study. Broadly speaking, as we observed in Chapter II, the subject of induced innovation is only beginning to take a formal shape and requires explorations along different directions. Regarding the specific line of study pursued in this study, it is possible to modify and/or extend it in several ways, some of which are listed below.

(a) Our study was cast in a partial equilibrium framework. General equilibrium considerations can be introduced into it by analyzing the effects of technical change on the demand side. In particular, the change in income generated by supply shifts may lead to demands shifts which merits attention in this context.

(b) We refrained from examining the cross effects of technical change among various competing crops. In the context of our study, technical change in jute production may shift more resources from rice to jute. Incorporation of this effect will provide an interesting topic for further study. Potential cross price effects on the demand side should also be examined.

(c) Another direction in which the present work can be extended is to lay more stress on the distributional aspects of technical change. Our study focused on the distribution between producers and consumers only. We observed that the producers will lose from technical change in rice production. However, given that they are also consumers of rice, it may be possible that they are still better off on balance. We were unable to incorporate a deeper study of the effects of technical change on this distribution and also on income and employment of factors due to lack of data and time. These can form an excellent basis for future study.

(d) The cost functions can be modified by specifying more realistic versions for them. This, again, will require first hand data from the research centres. As a result, similar study may be taken up by someone with access to such centres. First hand information on other aspects of technical change can also be utilized to build a more disaggregated model by integrating the first flow chart of Chapter IV with the model presented in Chapter V.

(e) Future research work can be initiated by modifying the benefit functions as well. In this study such functions were developed in terms of total surplus accruing to the society. Some of the other possible ways to measure the benefits from new technology are to estimate, a la Schultz (op. cit.) and Peterson (1967), the value of inputs saved or to estimate the amount of foreign exchange earned and/or saved.8

To sum up, we have presented a fairly detailed study of induced technical change in agriculture focusing on the allocation of funds for research and extension works.

Judging by the published literature, this is one of the pioneering studies in this area. We do not claim it to be a perfect analysis. However, given the limitations of time, space, and data, there was little scope for extending the study beyond this. The job of modification and extension, which knows no end, is left on the shoulders of future devotees of knowledge, including ourselves.

FOOTNOTES TO CHAPTER VII

1. It should be noted that if all relative prices stay the same over this period then the reference utility level is constant (ignoring growth) and this type of projection will be formally acceptable.

2. The exchange rate was calculated by taking an average of different monthly rates reported in various issues of the International Financial Statistics, 1978; published by the I.M.F.

3. From the F.A.O. Commodity Review and Outlook, we calculated the proportion of Bangladeshi jute consumed domestically which was applied to the information supplied by the Statistical Yearbook of Bangladesh, 1978 to arrive at Table 7.6.

4. Although never stated explicitly, we have assumed that h(i) is a continuous function. In that case the planner may aim at any value for it within the range specified.

5. See the Annual Development Plan for 1978-79 issued by the Government of Bangladesh.

6. Working on the ex post effects of technical change in Japanese rice cultivation, Hayami and Akino (1977) also found similar evidence of negative producers surplus.

7. See Chapter II (Section II.2).

8. The method of calculating benefits by the value of inputs saved is discussed briefly in Chapter IV (Section IV.6) of the thesis.

APPENDIX A

Induced technical change describes the change of technical production process to those which increase output from initial, pre-change, levels and/or result in the use of new input ratios which favour the relatively abundant resources available to producers. This change is frequently reflected by the introduction of new or "non-traditional" factors of production which we described in the text as modern inputs. Consequently, an analysis of the demand for these non-tradtional inputs merits special attention. We have seen that the expansion of bio-chemical technology releases the constraint on land by raising its yield, while the expansion of mechanical technology tends to replace labour and raise its productivity. For a land scarce, labour surplus economy like Bangladesh the expansion of bio-chemical technology is of greater significance. Fertilizer is one of the major elements in bio-chemical technology and its consumption has been increasing steadily in Bangladesh. In this Appendix, we plan to present an analysis of the market for fertilizer in Bangladesh which focuses on both the demand and supply situations. The findings of this analysis have been used in interpreting some of the arguments of the main text.

The study of the demand for fertilizer presented here is based on time series data and is similar to the works of Griliches (1958), Heady and Yeh (1959), Hayami (1969), Parikh (1965), Hsu (1972) and Salam (1975). Broadly speaking, these studies used time series data on the consumption of fertilizer in different countries of the world and regressed it on variables such as the real price of fertilizer, prices of the farm products, the amount of funds spent on agricultural research and extension programmes, total acreage and irrigated acreage, and the agricultural wage rate. Most of these studies found that the above mentioned variables were significant in explaining the domestic use of fertilizer.

On the basis of the studies cited above, we can postulate that in Bangladesh the demand for fertilizer should be a function of its price, acreage under fertilizer using crops, income of the farmer, price of the fertilizer using crops and the availability of the complementary inputs. Since this is a new factor in Bangladeshi agriculture, the farmer's familiarity with fertilizer is also likely to be an important variable in the demand function. The data on the last two variables are not readily available. However, both these variables are greatly influenced by the activities of the public sector extension workers who are also responsible for spreading mechanized irrigation in the rural areas. As such, they should reveal a high degree of collinearity, and the amount of land irrigated by modern techniques can be regarded as a proxy for the above factors. Since rice is the primary fertilizer using crop in Bangladesh and since it also constitutes the largest share of the country's agricultural output, the price of rice and the income of the farmer will be highly correlated if the costs of production do not change much. Consequently, the former variable has been used as representative of both influences.

Now we are in a position to hypothesize a demand function for fertilizer of the following form. The equation is specified in log-linear terms as it yielded a better result when compared with the linear version and has been written without explicit introduction of the time subscript.

$$\text{(A.1)} \quad \ln FDEM = a(1) + a(2)\ln ACR + a(3)\ln PFER + a(4)\ln PR(-1) + a(5)\ln IRRIG + a(6)\ln WAGR + \text{error term}$$

where,

FDEM : demand for fertilizer

ACR : acreage under fertilizer using crops

PFER : price of fertilizer

PR(-1): price of rice in the last period

IRRIG : amount of land irrigated by modern techniques

a(i) : regression coeffcients, i = 1.......6.

In actual estimation we had to drop the acreage variable due to the non-availability of disaggregated data on land where fertilizer is applied. Estimation of this equation by ordinary least squares is justified by the fact that fertilizer is heavily subsidized by the government so that the price of fertilizer can be treated as exogenous. The estimated equation is reported below:

$$\text{(A.2)} \quad \ln FDEM = \underset{(2.67)}{89.68^{**}} - \underset{(-3.39)}{0.11\ln PFER^{**}} - \underset{(-0.17)}{0.18\ln PR(-1)^{***}} + \underset{(12.79)}{0.08\ln IRRIG^{*}} + \underset{(0.004)}{0.002\ln WAGR^{***}}$$

R^2 = .96; Durbin-Watson Statistics = 1.57
Figures in the parentheses are respective t-scores

* : Significant at 99 per cent
** : Significant at 95 per cent
*** : Not significant at 90 per cent

In the above equation, we find that the crop price variable is not significant at any accepted level of probability which is also the case with the agricultural wage rate. All other variables have the proper sign and are significant at the 95 per cent level or higher. It is interesting to note that the level of irrigation which has been identified as a proxy for certain important cultural practices assumed a highly significant value. The price of fertilizer had a negative influence on its demand. This indicated that the farmers were appropriately concerned about the price of this factor and the policy of subsidizing fertilizer, actually pursued by the government, would, then, have motivated the farmers to purchase it from the market.

The analysis of the fertilizer market reveals an interesting paradox. Despite the fact that the subsidized selling price of fertilizer in Bangladesh is much lower than in neighbouring countries and despite the fact that a heavy subsidy has made fertilizer highly attractive, the actual demand for fertilizer in Bangladesh has always lagged behind the potential demand for it.[1,2,3] This is evident from Table A.1 below, which presents the actual demand for fertilizer and its availability in Bangladesh during the period 1963 to 1973.

TABLE A.1

CONSUMPTION AND AVAILABILITY OF FERTILIZER IN BANGLADESH DURING 1963-73 (In Tons)

Year	Domestic Availability	Total Consumption	Excess Supply
1963-64	122,733	111,207	11,526
1964-65	115,022	101,662	13,360
1965-66	242,021	129,053	112,968
1966-67	245,191	168,048	77,143
1967-68	256,501	226,870	29,631
1968-69	216,248	237,492	-21,244
1969-70	354,251	277,231	77,020
1970-71	308,376	305,955	2,421
1971-72	Not Available		
1972-73	386,000	384,021	1,979

Source: Various issues of Bangladesh Agriculture in Statistics and Statistical Yearbook of Bangladesh; and our estimate.

Unfortunately, the lack of availability data for years beyond 1973 prevented us from extending this further. However, the recent issue of the Bangladesh Economic Survey (1978-79) has observed that during 1978 there was excess supply in the fertilizer market in Bangladesh which is consistent with the findings reported in Table A.1. From the Table it appears that with the exception of the year 1968-69, the supply of fertilizer in Bangladesh was always greater than the demand. This implies that the farmers are not eager to purchase fertilizer despite its financial attractiveness which tends to support the view that the demand for fertilizer is influenced by a greater extent by the non-price factors. The fact that the coefficient of the irrigation variable used here as a proxy for the availability of package inputs turned out to be highly significant corroborates the above statement. The finding is also consistent with the Hayami-Ruttan interpretation of the development of fertilizer responsive crop varieties. They contended that with existing seeds and under the prevalent atmosphere of cultivation, traditional varieties will perform better without additional doses of fertilizer.[4]

FOOTNOTES TO APPENDIX A

1. The selling prices of fertilizer per 100 kilogrammes at the farmgate were the following in 1965-66. India: \$36.7, Sri Lanka: \$25.1, Japan: \$25.4, Nepal: \$58.7, Philippines: \$35.8, Thailand: \$27.9, Burma: \$36.9 and Bangladesh: \$17.4. The comparison of prices for other years is similar to this, see F.A.O. Production Yearbooks.

2. One estimate by the Kahnert et al. (1970) shows that the returns per Taka invested in fertilizer is 10.5 Takas for local rice varieties and 19.0 Takas for high yielding varieties of rice. It is possible that the Kahnert et al. estimate was done in ideal condtions which may be unattainable by the typical farmer.

3. It is very difficult to arrive at a figure which can be identified as the potential level of demand for fertilizer in Bangladesh. Despite its financial attractiveness, the farmers may be unwilling to step into the era of chemical fertilizers for many reasons. The major reason for this is, of course, crop uncertainty. About seventy per cent of the rice crop in Bangladesh grows under rainfed conditions. The risk associated with crops grown in that situation is quite high. But even after assuming that the demand for fertilizer by the growers of rainfed rice is zero, we are left with a huge potential demand for it. Based on the recommended dose for fertilizer for non-rainfed rice, cited in Kahnert et al., the potential demand works out to be 726 thousand nutrient tons in 1974. To this one has to add the other potential fertilizer demands that might come from growers of crops such as jute, sugarcane and tea.

4. See Hayami and Ruttan (1971), p.57.

BIBLIOGRAPHY

Abel, M. and D. Welsch (1977); Environmental Constraints, Commodity Mix and Research Resource Allocation, in T. Darymple and V. Ruttan, eds., Resource Allocation and Productivity in National and International Agricultural Research. Minneapolis: University of Minnesota Press.

Abramovitz, M. and P. David (1973); "Reinterpreting Economic Growth: Parables and Realities of the American Experience", American Economic Review, vol.58, no.2.

Ahmad S. (1966); "On the Theory of Induced Innovation", Economic Journal, vol.LXXVI.

_____. (1967a); "Reply to Professor Fellner", Economic Journal, vol.LXXVII.

_____. (1967b): "A Rejoinder to Professor Kennedy", The Economic Journal, vol.LXXVII.

Ahmad, S. and A. Kubursi (1979); Induced Adjustment and the Role of Agriculture in Economic Development: A Case Study of Egypt and Syria, in A.Zahlan, ed., Technology Transfer and Change in the Arab World. London: Pergamon Press.

Ahmad, S. (1980); Technological Progress and Income Distribution in Bangladesh Agriculture, unpublished Ph.D. thesis, Yale University, New Haven, Conn.

Ahmed, I. (1972); Unemployment and Underemployment in Pakistan (and Bangladesh), unpublished Ph.D. thesis, Iowa State University, Ames, Iowa.

_____. (1976): "Employment Effects of the Green Revolution", Bangladesh Development Studies, vol.IV, no.1.

Ahmed, F. (1974); Migration and Employment in a Multisector Model: An Application to Bangladesh, unpublished Ph.D. thesis, Prineton University, Princeton, New Jersey.

Ahmed, S. (1978); Rural Urban Interaction in Economic Development, unpublished Ph.D. thesis. McMaster University, Hamilton, Ontario.

Alamgir, M. and L. Berlage (1973); "Foodgrain Demand, Import and Price Policy for Bangladesh", Bangladesh Development Studies, vol.1, no.1.

Allen, R. (1968); Mathematical Analysis for Economists, London: English Language Book Society.

Alvin, P. (1976); Cocoa Research in Brazil, in J. Simmons, ed., Cocoa Production: Econometric and Botanical Perspectives. New York: Prager Publishers.

Anderson, R. (1975); Increasing Research Competence in Developing Nations, in The Agribusiness Council, ed., Agricultural Initiative in the Third World. Lexington: Lexington Books.

Asher, E. (1972); "Industrial Efficiency and Biased Technical Change in American and British Manufacturing: The Case of Textiles in the Nineteenth Century", Journal of Economic History, vol.32, no.2.

Askari, H. and J. Cummings (1973): "Factors Affecting Farmer Responsiveness to Price", Asian Economic Review, vol.15.

_____. (1976): Agricultural Supply Response: A Survey of the Econometric Evidence. New York: Prager Publishers.

Barnes. A. (1967); Agriculture of the Sugarcane. London: Leonard Hill Ltd.

Barletta, N. (1970); Costs and Social Benefits of Agricultural Research in Mexico, unpublished Ph.D. thesis, University of Chicago, Chicago, Illinois.

Bateman, M. (1965); "Aggregate and Regional Supply Functions for Ghanaian Cocoa, 1946-62", Journal of Farm Economics, vol.47.

_____ (1968); Cocoa in the Ghanaian Economy: An Econometric Analysis. Amsterdam: North Holland Publishing Company.

Behrman, J. (1968); Supply Response in Underdeveloped Agriculture: A Case Study of Four Major Annual Crops in Thailand, 1937-63. Amsterdam: North Holland Publishing Company.

Ben-Zion, U. and V. Ruttan (1978); Aggregate Demand and the Rate of Technical Change, in H. Binswanger and V. Ruttan, eds., Induced Innovation, Technology, Institution and Development. Baltimore: The Johns Hopkins University Press.

Binswanger, H. (1973); The Measurement of Biased Efficiency Gains in the U.S. and Japanese Agriclture to Test the Induced Innovation Hypothesis, unpublished Ph.D. thesis, North Carolina State University, Raleigh, N.C.

______. (1974a); "The Measurement of Technical Change Biases with Many Factors of Production", American Economic Review, vol.64.

______. (1974b); "A Microeconomic Approach to Induced Innovation", Economic Journal, vol.84.

______. (1978); Articles in Chapters 2, 4, 5, and 7; in H. Binswanger and V. Ruttan, eds., op. cit.

Black, J. (1953); Introduction to Economics for Agriculture. New York: Macmillan and Company.

Bonnen, J. (1970); The Absence of Knowledge of Distributional Impacts: An Obstacle to Effective Policy Analysis and Decision, in R. Haveman and J. Margolis, eds., The Analysis and Evolution of Public Expenditures: The PPB-System. Chicago: Markham Publishing Company.

Bose, S. (1968); "Trends of Rural Income of the Rural Poor in East Pakistan, 1949-66", Pakistan Development Review, vol.VIII, no.3.

Bose, S. and E. Clark (1969); "Some Basic Considerations on Agricultural Mechanization in West Pakistan", Pakistan Development Review, vol.IX, no.3.

Buchannan, J. (1968); The Demand and Supply of Public Goods. Chicago: Rand McNally and Company.

Butler, G., R. Banerji, and M. Yudelman (1971): Technical Change in Agriculture and Employment in Developing Countries. Paris: O.E.C.D.

Chandler, R. (1975); New Devlopments in Rice Research, in The Agribusiness Council, ed., op. cit.

Clark, R. (1957); "The Economic Determinant of Jute Production", F.A.O. Monthly Bulletin of Agricultural Economics and Statistics, vol.III, no.9.

Cummings, J. (1974); "The Supply Response of Bangalee Rice and Cash Crop Cultivators", Bangladesh Development Studies, vol.2.

David, P. (1975); Technical Choice Innovation and Economic Growth. London: Cambridge University Press.

David, P. and T. Van de Klundert (1965); "Biased Efficiency Growth and Capital-Labour Substitution in the U.S., 1899-1960", American Economic Review, vol.55, no.3.

Dayananda, M. (1977); Potential Cartelization in a Monopsonistic Market Structure: A Model of the World Tea Market, with special reference to Sri Lanka, unpublished Ph.D. thesis, McMaster University, Hamilton, Ontario.

De Janvry, A. (1973); "A Socioeconomic Model of Induced Innovation for Argentine Agricultural Development", Quarterly Journal of Economics, vol.87.

Dupuit, M. (1844); "On the Measurement of the Utility of Public Works", Annales des Ponts et Chaussees, 2nd Series, 8.

Evenson, R. (1968); The Contribution of Agricultural Research and Extension to Production, unpublished Ph.D. thesis, University of Chicago, Chicago, Illinois.

_____. (1969); International Transmission of Technology in the Production of Sugarcane, Mimeograph, Yale University, New Haven, Connecticut.

_____. and D. Jha (1973); The Contribution of Agricultural Research Systems to Agricultural Production in India, Indian Journal of Agricultural Economics, vol.28, no.4.

_____. and Y. Kislev (1973); "Research Productivity in Wheat and Maize", Journal of Political Economy, vol.81.

_____. and _____. (1975); Agricultural Research and Productivity. New Haven: Yale University Press.

Farashuddin, M. (1979); Shadow Prices of Labour, Investment, Foreign Exchange and Fiscal Resources - A Second Best Disequilibrium Approach for Bangladesh, unpublished Ph.D. thesis, Boston University, Boston, Mass.

Feeny, D. (1976); Technological and Institutional Change in Thai Agriculture, 1880-1940", unpublished Ph.D. thesis, University of Wisconsin, Madison, Wisconsin.

_____. (1979); Comment on the Grabowski (1979) Paper, unpublished Mimeograph, McMaster University, Hamilton, Ontario.

Fellner, W. (1961); "Two Propostions in the Theory of Induced Innovation", Economic Journal, vol.LXXI.

______ . (1962); Does the Market Direct Relative Factor-Saving Effects of Technological Progress?, in R. Nelson, ed., The Rate and Direction of Inventive Activity: Economic and Social Factors. Princeton: Princeton University Press.

______ . (1971); "Empirical Support for the Theory of Induced Innovation", Quarterly Journal of Economics, vol.85, no.4.

F.A.O. (1975); Domestic Prices of Jute in Bangladesh. Rome: Italy.

______ ; Commodity Review and Outlook; various issues.

______ ; Production Yearbook; various issues.

______ ; Trade Yearbook; various issues.

Geertz, C. (1966); Agricultural Involution. Berkley: University of California Press.

Goodwin, R. (1947); "Secular and Cyclical Aspects of the Multiplier and Accelerator", in L. Metzler et al., eds., Income, Employment and Production: Essays in Honour of Alvin M. Hansen. New York: W.W. Norton and Company.

Government of Bangladesh; First Five Year Plan.

______ . Statistical Yearbook of Bangladesh, various issues.

______ . Bangladesh Agriculture in Statistics, various issues.

______ . Annual Development Plan, 1978-79.

______ . Bangladesh Economic Survey, 1978-79.

Government of Pakistan; Report of the Jute Enquiry Commission (1960).

______ . Joint Pakistan American Agricultural Research Review Team (1968).

______ . Third Five Year Plan.

Grabowski, R. (1979); "The Implications of an Induced Innovation Model", Economic Devlopment and Cultural Change, vol.27, no.4.

Grilliches, Z. (1957); "Hybrid Corn: An Exploration of the Economics of Technological Change", Econometrica, vol.25.

______. (1958); "Research Costs and Social Returns: Hybrid Corn and Related Innovations", Journal of Political Economy,vol.66.

______. (1961); "A Note on the Serial Correlation Bias in Estimates of Distributed Lags", Econometrica, vol.29.

______. (1964); "Research Expenditures, Education and the Aggregate Agricultural Production Function", American Economic Review, vol.54, no.6.

______. (1967); "Distributed Lags: A Survey", Econometrica, vol.35 no.1.

Hayami, Y. (1969); "Demand for Fertilizer in the Course of Japanese Agricultural Development", Journal of Pollitical Economy, vol.46.

______. and M. Akino (1977); Organization and Productivity of Agricultural Research System in Japan, in T. Arndt, D. Darymple and V. Ruttan, eds., op. cit.

______. and V. Ruttan (1970); "Factor Prices and Technical Change in Agricultural Development: The U.S. and Japan, 1880-1960, Journal of Political Economy, vol.LXXVIII.

______. and ______. (1971); Agricultural Development- An International Perspective. Baltimore: The Johns Hopkins University Press.

______. and ______. (1973); "Induced Innovation and Agricultural Development", in B. Eliezer, ed., Micro Aspects of Development. New York: Prager Publishers.

______. and S. Yamada (1968); Technological Progress in Agriculture, in L. Klein and K. Ohkawa, eds., Economic Growth: The Japanese Experience Since the Meiji Era. Homewood: Richard D. Irwin, Inc.

Heady, E. (1949); "Basic Economic and Welfare Aspects of Farm Technologidal Advance", Journal of Farm Economics, vol.31.

______. and M. Yeh (1959); "National and Regional Demand Functions for Fertilizer", Journal of Farm Economics, vol.41.

Helleiner, R. (1977); International Technology Issues: Southern Needs and Northern Responses, in J. Bhagwati ed., The New International Economic Order: The North-South Debate. Cambridge: M.I.T. Press.

Hertford, R. et al. (1977); Productivity of Agricultural Research in Colombia, in T. Arndt, D. Darymple, and V. Ruttan, eds., op. cit.

Hicks, J. (1932); The Theory of Wages. London: Macmillan and Compamy.

______. (1940); "The Rehabilitation of Consumers Surplus", Review of Economic Studies, vol.8, no.2.

______. (1946); Value and Output. Oxford: Oxford University Press.

Hines, J. (1972); The Utilization of Research for Development: Two Case Studies in Rural Modernization and Agriculture in Peru, unpublished Ph.D. thesis, Princeton University, Princeton.

Hsu, R. (1972); "The Demand for Fertilizer in a Developing Country: The Case of Taiwan, 1950-1966", Economic Development and Cultural Change, vol.20.

Hussain, S. (1964); "A Note on Farmers' Response to Price in East Pakistan", Pakistan Development Review, vol.IV., no.1.

I.B.R.D. (1974); Bangladesh: Development in a Rural Economy, Volume I: The Main Report. Washington, D.C.

I.M.F. International Financial Statistics, various issues.

Johnston, J. (1972); Econometric Methods. New York: MgGraw-Hill Book Company, Inc.

Kahlon, A. et al. (1977); Returns to Investment in Agricultural Research, in T. Arndt, D. Darymple, and V. Ruttan, eds., op. cit.

Kahnert, F. et al. (1970); Agriculture and Related Industries in Pakistan. Paris: O.E.C.D.

Kaneda, H. (1969); "Economic Implications of the 'Green Revolution' and the Strategy of Agricultura Development in West Pakistan", Pakistan Development Review, vol.IX, no.2.

Kennedy, C. (1964); "Induced Bias in Innovation and the Theory of Distribution", Economic Journal, vol.LXXIV.

Khan, A. (1972); An Economic Analysis of 1980 International Trade in Jute with special reference to Pakistan, unpublished Ph.D. thesis, University of Wisconsin, Wisconsin.

Klein, L. (1958); "The Estimation of Distributed Lags", Econometrica, vol.26, no.4.

Kmenta, J. (1971); Elements of Econometrics. New York: Macmillan Publishing Company.

Koyck, L. (1954); Distributed Lags and Investment Analysis. Amsterdam: North Holland Publishinig Company.

Layard, R. (1972); Cost-Benefit Analysis. Harmondsworth: Penguin.

Lucas, R. (1967); "Tests of a Capital-Theoretic Model of Technological Change", Review of Economics and Studies, vol.34.

Malinvaud, E. (1966); Statistical Methods of Econometrics. Amsterdam: North Holland Publishing Company.

Marshall, A. (1920); Principles of Economics. London: Macmillan and Company.

Mishan, E. (1976); Costt Benefit Analysis. New York: Prager Publishers.

Mujeri, M. (1978); The World Market for Jute: An Econometric Analysis, unpublished Ph.D. thesis, McMaster University, Hamilton, Ontario.

Muqtada, M. (1975); "The Seed-Fertilizer Technology and Surplus Labour in Bangladesh Agriculture", Bangladesh Development Studies, vol.III, no.4.

Muth, J. (1961); "Rational Expectations and the Theory of Price Movements", Econometrica, vol.29.

Nelson, R. (1959); "The Economics of Invention", The Journal of Business, vol.32, no.2.

Nerlove, M. (1958); The Dynamics of Supply: Estimates of Farmers' Response to Price. Baltimore: The Johns Hopkins University Press.

Ogura, T.,ed. (1963); Agricultural Development in Modern Japan. Tokyo: Fuji Publishing Company Ltd.

Parikh, A. (1965); "Demand for Nitrogenous Fertilizers: An Econometric Study", Indian Journal of Agricultural Economics, vol.II.

______. (1971); "Farm Supply Response: A Distributed Lag Analysis", Bulletin of the Oxford University Institute of Economic and Statistics, vol.33, no.1.

Peterson, W. (1967); "Returns to Poultry Research in the U.S.", Journal of Farm Economics, vol.49.

______. (1971); The Returns to Investment in Agricultural Research in the U.S., in W. Fishel, ed., Resource Allocation in Agricultural Research. Minneapolis: University of Minnesota Press.

______. et al. (1977); Organization and Productivity of the Federal-State Research System in the U.S., in T. Arndt, D. Darymple, and V. Ruttan, eds., op. cit.

Pinstrup-Anderson, P. (1974); Toward a Workable Management Tool for Resource Allocation in Applied Agricultural Research in Developing Countries, Mimeograph, C.I.A.T., Cali, Colombia.

Rabbani, A. (1964); Jute in the World Economy- A Statistical Study, unpublished Ph.D. thesis, University of London, London.

Rajagopalon, V. and M. Meenakhsisundaram (1969); "Travails of Tea Industry", Indian Journal of Agricultural Economics, vol.XXIV, no.3.

Rajagopalon, V. et al. (1971); "Price Elasticities- Mehtodological Issues with respect to Perennial Crops", Indian Journal of Agricultural Economics, vol.XXVI, no.4.

Ramalho De Castro, J. (1974); An Economic Model for Establishing Priorities for Agricultural Research and a Test for the Brazilian Economy, unpublished Ph.D. thesis, Purdue University, Purdue, Illinois.

Rosenfield, A. (1955); Sugarcane Around the World. Chicicago: University of Chicago Press.

Ruttan, V. (1959); "Usher and Schumpeter on Invention, Innovation and Technological Change", Quarterly Journal of Economics, vol.73.

_____. (1971); "Technology and the Environment", American Journal of Agricultural Economics, vol.53, no.5.

_____. (1978); Induced Institutional Change, in H. Binswanger and V. Ruttan, eds., op. cit.

_____., H.Binswanger, and Y. Hayami (1977); Induced Innovation in Agriculture, Paper presented at the Fifth World Congress of the International Economic Association held in Tokyo, Japan.

Salam, A. (1975); Economic Analysis of Fertilizer Application in Punjab-Pakistan, unpublished Ph.D. thesis, University of Hawaii, Honolulu, Hawaii.

Salter, W. (1960); Productivity and Technical Change. Cambridge: Cambridge University Press.

Samuelson, P. (1965); "A Theory of Induced Innovation along Kennedy-Weizacker Lines", Review of Economics and Statistics, vol.47.

Sanders, J. and V. Ruttan (1978); Biased Choice of Technology in Brazilian Agriculture, in H. Binswanger and V. Ruttan, eds., op. cit.

Schmitz, A. and D. Seckler (1971); "Mechanized Agriculture and Social Welfare: The Case of Tomato Harvester", American Journal of Agricultural Economics, vol.52, no.4.

Schmookler, J. (1966); Inventions and Economic Growth. Cambridge: Harvard University Press.

_____. (1972); Patents, Invention and Economic Growth: Data and Selected Essays. Cambridge: Harvard University Press.

Schultz, T. (1953); The Economic Organization of Agriculture. New York: MgGraw-Hill Book Company, Inc.

Seckler, D. (1970); Reflections on Management, Scale, and Mechanization of Agriculture, Proceedings of the

Western Agricultural Economics Association, 43rd Annual Meeting, Tucson, Arizona. Corvallis: Oregon State University Press.

Sen, A. (1959); "The Choice of Agricultural Techniques in Underdeveloped Countries", Economic Development and Cultural Change, vol.7.

Shorter, F. (1955); "Jute Production Policies of India and Pakistan", Indian Economic Journal, vol.III, no.1.

Sinha, A. (1941); "A Preliminary Note on the Effects of Price on Future Supply of Raw Jute", Sankhya, vol.5, part 4.

Smith, C. (1979); "The Similarity of Opportunity Cost and Social Discount Rate when Measured in Real Terms", Journal of Agricultural Economics, vol.XXX, no.1.

Solo, R. and E. Rogers (1972); Inducing Technological Change for Economic Growth and Development. Lansing: Michigan State Universty Press.

Staub, W. and M. Blase (1973); "Induced Technological Change in Developing Agricultures: Implications for Income Distribution and Agricultural Development", Journal of the Developing Areas, vol.8, no.4.

Sugden, R. (1979); "The Measurement of Consumers' Surplus in Practical Cost Benefit Analysis", Applied Economics, vol.11, no.2.

Tang, A. (1963); "Research and Education in Japanese Agricultural Development", Economic Studies Quarterly, vol.13.

Timmer, C. (1969); "The Turnip, the New Husbandry, and the English Agricultural Revolution", Quarterly Journal of Economics, vol.83.

Tweeten, L. and L.Quance (1969); "Positivistic Measures of Aggregate Supply Elasticities: Some New Approaches", American Journal of Agricultural Economics, vol.51, no.4.

Ullah, A. (1974); Farm Productivity, Returns to Scale, and Technological Change in a Traditional Agriculture: A Case Study of Bangladesh, unpublished Ph.D. thesis, Harvard University, Cambridge, Mass.

Uphoff, N. and W. Ilchman (1972); Development in the Perspective of Political Economy , in N. Uphoff and W. Ilchman, eds., The Political Economy of Development. Berkley: University of California Press.

Wade, W. (1973); Institutional Determinants of Technical Change and Agricultural 1 Productivity Growth: Denmark, France and Great Britain, 1880-1965, unpublished Ph.D. thesis, University of Minnesota, St. Paul, Minnesota.

Weber, A. (1973); Productivity Growth in German Agriculture: 1850 to 1970, Staff Paper P73-1, Department of Agricultural and Applied Economics, University of Minnesota, St. Paul, Minnesota.

Willig, R. (1976); "Consumers Surplus without Apology", American Economic Review, vol.66, no.4.

Winch, D. (1971); Analytical Welfare Economics. Harmondsworh: Penguin.

Yamada, S. and V. Ruttan (1975); International Comparisons of Productivity in Agriculture, Paper presented at the N.B.E.R. Conference on Research in Income and Wealth, Williamsburg, Virginia.