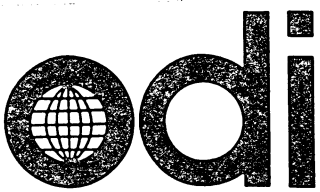

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A MULTIPLE SOURCE OF INNOVATION MODEL OF AGRICULTURAL RESEARCH AND TECHNOLOGY PROMOTION

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CONTENTS

Preface and Acknowledgements

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Abstract

This paper describes and contrasts two models of agricultural research and technology diffusion. One model is the central source of innovation model (central model) which frequently underlines the theories and rhetoric of agricultural research and extension institutions. The other is the multiple source of innovation model (multiple model) which describes agricultural research and diffusion processes in the context of the historical, political, economic, agro-climatic and institutional setting in which technological change takes place. An important paradox is examined, namely, that research practitioners and managers of research funds generally use the central model in their work in research and extension systems, when often they have many experiences which counter-act the validity of central model.

The paper concludes by reviewing the implications and significance of the multiple model for (1) the conceptual framework of agricultural research and technology promotion, (2) the language of research and extension, global and national, (3) agricultural research resource allocation policy, and (4) the role of methods and techniques for agricultural research policy analysis.

I. INTRODUCTION

The main argument of this paper is that agricultural research and technology diffusion activities are always fundamentally integrated over time with political, economic and institutional events. The activities of agricultural research (science) cannot be separated from the use and spread of technologies. There is not, on the one hand, a "neutral", apolitical scientific R & D system which is steadily creating new innovations and pushing forward the frontiers of institutionalised academic knowledge and, on the other hand, the real world of technology users where political, economic and institutional forces determine how scientific knowledge applied. Science and technology use are continuously and inextricably interwoven with economic and political events.[1]

Two models (a central source of innovation model and a multiple source of innovation model) are compared here to illustrate the significance and implications of different approaches in understanding the behaviour of scientists and in agricultural research policy.[2] Two major differences between the models are: (1) do technical and institutional innovations come from the systematic work of research centres and get passed down to farmers, or do they come from a multitude of sources and often in unpredictable ways? and (2) is there a natural linear evolutionary path by which agricultural research and extension systems develop, or are agricultural research and extension systems always in disequilibrium and undergoing structural change as economic, administrative and scientific interest groups compete for the benefits of research and technological change?

In many situations a paradoxical situation is found. On the one hand the ideals and rhetoric of the central model are used all the time, while on the other hand the actual behaviour of people and institutions in research and extension systems is better explained by the multiple source model. Reasons for this paradox are discussed in the paper.

II. MODELS OF TECHNOLOGY GENERATION AND DIFFUSION

1. The Central Source Model

The most dominant model of research and promotion activities is the central model.[3] In its simplest form it is illustrated by Figures 1 and 2.

At the centre are international agricultural research centres such as the members of the Consultative Group of International Agricultural Research (CGIAR) and the Overseas Development Natural Resources Institute, London. Then there are national agricultural research systems, followed by national extension systems. On the periphery of the system are early adopting farmers followed by late adopting farmers.

Widely adaptable technology is generated in the centres and transferred (linkage 1) to national research system for adaptive research and finally to extension systems for transfer to farmers through demonstrations, advice and other promotional activities.

Information from farmers is fed back to the centre by a reverse set of linkages (linkage 2). In this way the priorities and programmes of the institutions of the centre are changed to keep focused on the technical problems of farmers. Major emphasis in the system is on the transfer of knowledge and technology from research centres to farmers.[4]

National and international agricultural research systems are linked up by networks for technology and information exchanges. These networks might cover germplasm exchanges or information about research methods and techniques, eg. the Asian Farming Systems Network. Frequently international centres form the hub or centre of these networks.[5] As regards the generation and diffusion of plant materials, the central model is exemplified

by the work of the International Rice Research Institute (IRRI). New varieties of rice have been developed by IRRI and transferred to developing countries.

In the area of institutional innovations, the central model is illustrated by the Academy for Rural Development in Comilla, Bangladesh. In the 1960s social science researchers developed new institutions in a "social" laboratory for the organisation and management of rural development at the village and the thana (block) level of public administration. Many observers at the time, and since then, have seen the Comilla two-tier (village and thana) cooperative model as a relevant and viable model for transferring to other parts of Bangladesh and even other countries.[6] In recent years some of the developers and advocates of new farming systems and on-farm research methods have also proceeded in this way.[7]

Key features of the central model are:

a. Role of Institutions

Specific unambiguous roles are given to specific institutions and groups of people. For example, research institutions have an international or a national mandate; or the job of an extension agency is to conduct extension work and not carry out any type of research. Farmers are seen as technology adopters or people who have problems which are fed back to extension advisers and to researchers.

b. Stages in Research and Extension Activities

Research is seen as a set of stages. Scientists develop technology at the centre which is adapted in subsequent stages before being demonstrated to farmers in the final stages. .

c. Stages in the Development of Research and Extension Capabilities

Research and extension capabilities are assumed either not to exist or to be of minor importance in developing countries until they have been transferred from centres in developed countries. The development of a local research capability follows only after the initial transfer of materials, then the transfer of practices of farm management, then the transfer of know-how and blueprints, and finally the transfer of a technology generation capacity as a result of institution building, training and staff transfers from developed countries or international centres of learning.[8]

d. Hierarchical Structure

The process of technology generation and promotion is hierarchical as illustrated in Figure 2. New materials and practices are generated and passed down the system. Feed-back passes back up the system (linkages 1 & 2 in figure 1). The training and visit (T & V) system of extension is a classic form of this type of hierarchical administrative structure.[9]

e. Networks for Materials and Information

In addition to the hierarchical linkages described above the central model has "neutral" networks for the exchange of materials and information. These are two-way exchanges between scientists. Unlike the transfer and feedback linkages no concepts of hierarchy are involved in these network exchanges. For example, because the dwarfing norin 10 genes, (which were critical to the success of the Mexican wheats which spread in Mexico and Asia) came from Japan, it is not said that Mexico, India and other countries have adopted Japanese technology. Nor is it said that IR36, the world's most widely cultivated rice variety developed by IRRI is an adaptation of Indian technology

because critical genes for resistance to grassy stunt came from a wild rice collected in Uttar Pradesh, India in 1963, by a scientist of the Indian Central Rice Research Institute (Plucknett, et al., 1987, pp 171-176).

The existence of the neutral networks can help reinforce the hierarchical nature of the central system. It would appear that often in the practice of research in the central mode that when the centre is getting information, materials and help from actors in other parts or lower down in the system then the flow of information etc. is called "feed-back" or a "neutral" networking activity. Frequently, little or no recognition is given to the source or the importance of the information. However, when information, materials, etc. go out from the centre to other actors in the system then the centre gives the information or technology its own label or identifies it in some way so that it is seen as belonging to or coming from the centre.

f. Treatment of Time

The hierarchical model is strongly linear in its handling of time. This is reflected in three ways. First, the dominance of the logical, sequential, linear stages of a problem solving approach (eg. (1) problem diagnoses, (2) technology development, and (3) technology testing, and (4) technology dissemination). Second, the sequential stages in the building up of scientific institutions and research capability. Third, the implicit, if not explicit, idea is that knowledge, materials, technologies, and institutions, once "discovered", will automatically - as if guided by a hidden hand - be remembered, or stored and flow along one of the linkages or networks within the research and production knowledge system, and be systematically taken into account by scientists when making decisions about science policy and going about their daily work.

g. Definition of Technology and Research Institutions

Technology is treated as if it is something that can be defined quite unambiguously and can be developed and transferred as packages with different degrees of sophistication at different levels in the hierarchical system.[10] At the field level different farmer clients (eg. resource-rich or resource-poor) are targeted as the group to use different packages. At the research institution level different countries or geographic regions are classified as having an adaptive or an applied research capability. Therefore, they can or cannot receive and use packages of technology of different levels of sophistication. As regards packages of new research methods, different types of researcher clients in national research systems of developing countries are identified, and manuals of widely adaptable research tools and methods are designed at international centres for transfer to developing countries.

h. Sources of Innovation

The hierarchical model sees sources of significant new innovations as emanating from centres at the top of the system. Information and knowledge from farmers, from extension personnel, and from national research systems are "inputs" to be collected, screened and used selectively by those in the centre for generating new materials, management packages, blueprints, research methods, and institutional forms for transferring to people at lower levels. Informal research and experimentation by farmers,[11] innovations from extension agencies, and innovations from research practitioners at lower levels, innovations from administrators in large scale public and private organisations, and innovations from staff in non-government organisations (NGOS), are not seen as equally important sources of significant technological, institutional and methodological innovations.

i. Political, Funding and Institutional Context

In the central model as portrayed in Figure 1, there is no reference to the role that political, economic and institutional factors play in affecting the generation, promotion and use of agricultural technology. By having no reference to such "non-scientific" issues the model helps to encourage the idea that there is a natural evolutionary process by which appropriate technology and institutions for research and extension will be induced into existence, provided politics and biased funding of one kind or another are kept out of science. Politics with a big "P", ie. major international and national political considerations which determine whether funders of research allocate money to certain regions, countries, institutions, or crops, rather than others, are seen as difficult constraints on the work of "good scientists", but have nothing to do with what is defined as "good science" or relevance to what technology is developed and promoted. Politics with a small "p", ie. institutional politics, the jostling for funds, equipment, promotions, status and prestige within scientific and extension agencies, are seen as normal, everyday behaviour which scientists have to "put up with" and anyway, does not really have any long-term effect on the direction and content of the technology generation and diffusion process.

When using the central model for describing the history of technology generation and transfer, proponents of this approach will often, if only implicitly, claim that the successful spread of a technology was mainly a result of the R & D and perhaps the extension processes. Generally, reference is not given to the policy, economic, agro-climatic, and institutional contexts which were of at least equal importance as regards creating the conditions for the technology to spread. If reference is made to the many inventions of researchers in centres which are still lying "on the shelf", it is said that this is not a bad thing because it is the job of science to create a shelf of technology and not be too concerned about its diffusion. Alternatively,

some scientists say that the technology is good, but it is not being used because of a lack of political will on the part of "government" to promote the technology, or a lack of "appropriate" price policies, irrigation and infrastructural investment policies, institutional policies etc.

Some readers might feel that in this description of the central model an unrealistic "straw man" has been put up in order to knock it down. While this is true to some extent, it has been done here because of the dominance and pervasiveness of ideas, theories, language and practice that emanates from the central model is very great. The model has been presented in this way in order to highlight its difference from the multiple source model which places emphasis not only on multiple sources of innovation, but also on continuous disequilibrium in the system, tremendous diversities in agricultural research and extension institutions, a recognition that the direction of agricultural research, technological and institutional change is always guided by political, economic, and institutional factors, and that the behaviour of scientists and agricultural research and technology promotion institutions can be explained as much by "rent seeking", "profit seeking", and "revenue seeking" activities as by conventional ideas of good scientific practice.

2. Multiple Source Model

a. General Features

(i) The Political, Economic and Institutional Context

Some general features of the multiple source model are represented in Figure 3. It starts from a totally different premise from that of the central model. In the multiple source model all technology generation and promotional activities are seen to take place in an

historically defined political, economic, agro-climatic, and institutional context. This context is defined by the main circle in Figure 3 (point 1).

(ii) Institutions: Formal and Informal; Public, Private and NGOs

Within the circle are formal (institutionalised) and informal research and extension capabilities.[12] Formal institutions may be in the public sector, the private sector, or non-government organisations (NGOs).[13] The diverse institutions of research and extension are illustrated in Figure 4. In the past much social science analysis in agricultural research has concentrated on the transfer of technology to farmers through public and private sector organisations, but has not analysed informal R & D and diffusion processes, "feedback" processes, or linkages between public, private and NGO organisations.

(iii) The Historical Dimension

Figure 3 adds an historical dimension to the model. For example, point 2 on the diagram represents the creation of the International Rice Research Institute (IRRI) which, amongst other things, used previous work and genetic materials from the International Rice Commission's programme in Asia, the Central Rice Research Institute (CRRI) in India, and other national programmes such as those of Japan and Malaysia. Another example of where a new institution came into existence as a result of the recombination of previous research capabilities was the creation of the International Wheat and Maize Improvement Centre (CIMMYT). This incorporated a part of what had been the Mexican Wheat Improvement Programme and was joined by researchers with experiences and capabilities from the Indian wheat improvement programme. It is very difficult to assess the contributions of recent

international centres unless adequate attention is given to the major debt owed to these earlier programmes.

Point 3 represents a situation where there is very close contact between a research capability and promotion capability within one organisation, for example, in some large-scale multi-national corporations. In the Philippines the Bayer company, which had invested research funds in developing pesticides, had a promotion capability which drew up a multi-year high-level agreement with the National Irrigation Administration of the Philippines for the intensive demonstration and promotion of the company's product. Careful integrated pest management analysis has shown that the technology package being promoted by extension agencies and used by farmers was neither cost effective from the farmers' point of view nor relevant to national agricultural development goals (Kenmore, 1987).

This is a case of a transfer of a technology programme which had given profits to Bayer and returns to rent seekers in the public sector, but had wasted farmers' money and government funds.

In the public sector there are also examples of close linkages between research and promotion capabilities. For example, in Zimbabwe before independence, the public sector maize research and extension agency (Agritex) were closely integrated to work on the problems of white, large scale commercial farmers (Avila et al., 1987). In the Indian Punjab, during the late 1960s there was a very close integration between the Indian wheat research programme and government extension agencies. At the time the government subsidies for fertiliser, electricity to power irrigation pumps, and other agricultural inputs were considerable. There was a very substantial government intervention programme to maintain relatively high wheat prices and purchase wheat from farmers.

Point 4 represents a case of an informal research and diffusion. Over the years farmers in Nepal selected rice plants that performed better than other land rice varieties. One of the results was a variety called Pokhreli masino rice. This then spread amongst farmers in a specific ethnic group by farmer-to-farmer exchanges (Green, 1986). Recently, genes from this robust variety have been adopted by the IRRI's international rice improvement programme. In Guatemala, the spread of some introduced technology-contour ditches and Napier grass barriers has taken place as a result of informal extension activities on the part of farmers. In this case the World Neighbours and Oxfam staff involved actively promoted informal farmer experimentation and informal inter-farmer communication systems in order to strengthen the local informal R & D and diffusion systems.[14]

Point 5 represents a situation where there is overlap between formal and informal capabilities which is not formally recognised by the formal institution. For example, in some colonial situations the families of growers would interact at a social level with the families of researchers. Information and technology would flow in both directions in an informal way between farmers and researchers. Another informal situation of this kind is described by Grace Goodell where she found that Filipino labourers working on the IRRI research stations carried away seeds from breeding stocks and varieties which had not been released and gave or sold them to relatives and friends to test and experiment with on their own fields (Anderson, Levy and Morrison, 1988, p 12).

Point 6 represents a situation where an institution was involved in research, but over the years became more of a teaching institution. For example, the Academy for Rural Development in what is now Bangladesh, was established with a national mandate to conduct research on developing appropriate rural development institutions for the country. Although it gained international

fame its research activities declined as it was unable to adapt and change its programme in the light of changing political, economic and institutional circumstances.

Point 7 represents the lobbying and promotional capabilities of many rich country engineering consultancy companies and manufacturers of tractors, irrigation and other engineering equipment. The promotion of tractors in Asia through subsidies of various types by international donors and governments is a case of major international transfer of technology. This type of machinery was promoted on the grounds that it was needed in order to increase crop yields per hectare and cropping intensities. A major review of farm level evidence showed that neither of these objectives had been achieved as a result of tractorisation, but frequently labourers had been displaced from their jobs or tenants evicted from their holdings.[15]

Figure 3 could be used to illustrate many other situations found in the generation and promotion of agricultural technology. However, the "lumpy sausage" would be difficult to draw and even more difficult to digest! It is hoped that the Figure illustrates that material and institutional innovations come from multiple institutional and geographic sources and that political, economic and institutional factors have a major influence on processes of technology generation and diffusion.

In the next section some key specific features of the multiple source model are compared with the central model. These features are summarised in Table 1.

Specific Features:

a. User and Practitioner Innovations

In the central source model great emphasis is given to formal research centres as being the major sources of innovations. In

the multiple source model major emphasis is given to the idea that innovations come from multiple sources. There are very many diverse private, public and institutional actors in the research system, as well as farmers, artisans, etc. in the rural economy conducting informal research. Not only do innovations come from those who have been designated the role of "researchers", but they also come from "practitioners" in numerous settings throughout the research, extension and production system. [16] One of the reasons why "users" or "practitioner" research is often not recognised is because practitioners often do not think or realise how innovative they are being when addressing and solving problems. There are a number of research practitioners of this kind who immediately come to mind:

(i) Research-minded farmers: These are the farmers, village artisans, etc. who are always experimenting in one way or another and involved in informal R & D and diffusion activities. They have been discussed already.

(ii) Innovative Research practitioners:[17] Perhaps one of the most important findings of a recent study of client-orientated on-farm research is the critical and innovative role that some national and local research practitioners have played in developing suitable methods and administration structures for on-farm research in different places.[18] Sometimes this has been done with little or no contact from "outsiders" from western and international centres who have specific job descriptions to develop methods and techniques in this area for transfer to developing countries. Where there has been contact with outsiders, it has often been the innovative behaviour of local researcher managers who have "depackaged" the set of recommendations from advisers, selecting components relevant to local circumstances and discarding the rest. In some situations the centres

have been slow to adopt the advice of national research practitioners as regards the inappropriateness of the methods they were trying to promote and transfer. This was the case in Asia where the IRRI sponsored cropping systems network was developing methodology which neglected holistic household analysis and the importance of incorporating into the analysis non-crop technologies such as livestock and agro-forestry. Research practitioners in Nepal, who were part of an international cropping system network run by IRRI repeatedly pointed to this fundamental flaw in the methodology, but had to wait for several years before their knowledge and innovations were accepted and adopted.

(iii) Research-minded Administration Practitioners: There are numerous examples of unrecorded, innovative, research-minded administrators. In Bangladesh, Mr. L.R. Khan, a Joint Director in the Ministry of Rural Development, established a cell in the early 1970s to carry out rapid surveys in rural areas to assess the usefulness of innovations coming from various NGO and government agency rural development projects, and, where possible, to learn from them. He also created new government credit facilities within the Ministry of Rural Development for landless labourers and sharecroppers so they could purchase manually operated shallow tubewells for irrigation purposes. He worked in conjunction with research-minded innovative aid administrators in UNICEF, and with some scientific divisions of the USAID and the World Bank. One of the reasons why these institutional innovations spread only a little was because there was a strong bias against highly divisible, labour intensive technology for agricultural development amongst dominant government

and donor institutions. Government research and price policies were also biased against labour intensive technology (Biggs and Griffith, 1987).

In Bihar, Mr. Appu, the Kosi Area Development Commissioner, developed new administrative procedures for promoting the spread of a bamboo tubewell (which itself was a product of informal R & D by research-minded farmers and local artisans) (Clay, 1978; 1980).

These examples contrast sharply with the central model which sees "centres" as the primary source of innovation. In fact, on some occasions the role of the centres has been that of gathering and synthesising viable ideas, methods, etc. from informal R & D by farmers and local research practitioners and promoting them as methods and ideas for other international and national systems to adopt. Often it is very difficult to distinguish where critical innovative "inputs" originate.

(iv) Innovations from NGOs: There is a growing literature on how NGOs can play a complementary role to public sector agricultural R & D and extension systems. Frequently in the past, NGOs were characterised as relief institutions, or "extension" institutions. In other situations they worked in enclaves as "special projects" independent of government agencies. Increasingly it is being recognised that some NGOs and some parts of government institutions in some countries, work together innovatively and create, as they go along, new methods for the organisation and management of research and extension systems. Recent examples include in Guatemala, Bangladesh and Bolivia.[19]

(v) Innovations from Private Corporations: A further source of technologies and institutional innovation are large and small scale private corporations. There is a considerable literature on the outcomes of the activities of multinational corporations transferring agricultural technology to developing countries. One of the important features of private sector - as opposed to public, and NGO sector - research and promotion institutions is the declared goals of the institution involved. While private institutions may have many objectives, the primary objective is making profits in the short or long term. For the purposes of this paper it is critical to note that if one is looking at international agriculture research and technology promotion systems, the innovative activities of large multinational corporations and small firms have to be analysed explicitly as these have a major influence on technological change.

b. Behaviour of Agricultural Research and Extension Systems

A second key feature of the multiple source model is the recognition that agricultural research and technology diffusion systems contain a multitude of actors and institutions who have very diverse objectives. There are researchers of one type of another in international and national research systems, in private corporations, in extension systems, in NGOs, and in the local informal R & D system in rural societies. These institutions reward their researchers for performing in different ways:

(i) Research as Part of Profit Seeking Activities:[20] While it is reasonable to hypothesise that private corporations may be motivated by profits, one has to have another model for predicting the behaviour of international agricultural centres, and public sector national agriculture research and extension systems.

(ii) Research as a Rent Seeking Behaviour: It is suggested that as much of the direction and content of research in public sector research institutions (and in international research centres) is determined by the availability of funds, that research managers are, in some of their role, revenue and rent seekers.[21] Their job is to seek out - in the political, economic and institutional environment - sources of research funds. In national research and extension systems, whether funds are available for one purpose or another has a major influence on the direction of research and development activities. Supporters and critics of the green revolution strategies of Asia and the work of the international centres under the CGIAR umbrella are all agreed that the availability of research funds from such agencies as the Ford Foundation and the Rockefeller Foundation "opened up" new sources of funds for specific types of research for scientists who wanted to go in those directions.[22] This also led to behaviour on the part of those research centres to produce results and publicity that will ensure future funding. It would be strange to think of this behaviour on the part of research managers who were concerned with seeking future research revenue as not being a highly political and sensitive set of activities.

(iii) Research as Administrative Behaviour: A third set of features which helps to explain the behaviour of public sector research institutions are the reasons for why people hold their jobs and criteria for job performance. In many regards the organisation and management of large scale public sector research systems are similar to other public sector organisations. Staff want to keep their jobs, reports have to be written, accounts have to be kept, and large systems have to be managed. In donor organisations

and international centres money has to be disbursed, monitoring and evaluation concerns have to be carried out, and positive results have to be seen. Serious analysis of these administrative determinants also helps to explain the direction, content and viable output of research and extension systems.[23]

(iv) Research as an Academic Pursuit: There is also the set of criteria from science such as peer group reviews, and contributions to science which influence the direction and content of research and development activities. These are the criteria on which the central model places primary emphasis.

It is argued here that the multiple source model is more useful than the central model for understanding the direction and content of agricultural research and promotion systems as it sees profits, rent seeking, and the administrative objectives of researchers and institutions as influences on the direction of research and promotion systems which are at least as important as criteria which see science as only an academic pursuit.

c. Continuous Disequilibrium

A third key feature of the multiple source model is that it focuses attention on the continuous state of disequilibrium in which agricultural research and production activities take place. It is in this continuously changing situation that different economic, scientific and administrative interest groups go about their day-to-day activities.

III. THE PARADOX OF THE CENTRAL AND MULTIPLE SOURCES OF INNOVATION MODELS

The Paradox

The most dominant model that underpins the rhetoric of agricultural research is the central model. However, the multiple source model appears to better fit the practice of agricultural technology generation and diffusion.

It is useful at this point to consider some reasons for this apparent paradox.

1. Political Factors Which Influence the Allocation of Limited Research Resources to Benefit Different Groups of Farmers

While funds and time for research are finite, the number of problems that can be addressed are infinite. This means there is a political economy issue concerning the allocation of scarce research resources amongst competing alternatives. If we look at the past, it is clear that the ability to control and direct research resources in one direction rather than another are some of the major reasons why some research centres have flourished in various ways while others have declined.[24] The funding of the CGIAR international agricultural research centre is a clear example of where two major foundations (the Ford Foundation and the Rockefeller Foundation) made major interventions into the field of science and changed the direction of agricultural research towards major food grains. The political context also explains why some extension systems are supported by a research capability that changes its research programme in response to "feedback", while other extension systems are not listened to or give inadequate excuses for poor and irrelevant technology coming from research centres.

In applied agricultural sciences the political issue of defining specific groups of clients of research and extension is

especially important. Helping to improve technology for resource-poor farmers in a country is generally a far more difficult job than working for resource-rich. For researchers there is a question of why take on difficult jobs if there are easy ones to address. In addition, by working explicitly with one group of farmers rather than another, there is a great risk that the political bias of your research is seen. As a risk avoidance strategy, many researchers use the central model to justify their work. In that model, farmers are not defined specifically by their socio-economic position in society. They are just called "farmers".

Even in research programmes where the declared objective of projects was to help resource-poor farmers, it has been found that in the "implementation stage" that it was the better-off farmers who often gained the most. This was as a result of the political and economic context in which poor farmers, and the researchers who worked with them, had to operate. These are findings of a recent study of national agricultural research systems in nine countries concerning the organisation and management of client-oriented on-farm research.[25]

Another, and perhaps more important area that has been neglected by research policy, is agricultural and rural engineering. The central model, with its emphasis on the transfer of technology from developed to developing countries, fits very well with the export promotion activities of engineering companies in the developed world. These are power interest groups. Certain concepts such as the linear "stages in mechanisation" by which each country follows a natural progression of, for example, first mechanising tillage systems, then irrigation, and then draft power fit well with the central model. Those economists who see the world in this way generally advocate the need to modernise traditional agriculture in developing countries with modern equipment. The evidence though is that countries mechanise in unique ways, depending on the political, economic and

institutional context, and much inappropriate mechanical equipment has been transferred to or developed in developing countries partly as a result of this approach.

The central model enables us to sweep politics under the carpet, as if these issues are not important and research is a non-political, neutral activity.[26] The model keeps attention on the problems of "farmers" rather than "which group of farmers". If groups are defined, they are by commodities (eg. wheat farmers) or regions (eg. hills or plains), or as early or late adopters, but not by socio-economic group.

2. Elitism of Education and Research

A major reason why the central model is so dominant lies in the elitist orientation of some education and research programmes. The central model fits very well with the view that farmers are ignorant, even "backward and traditional", and are people to be helped by those in research and extension systems with formal education. By contrast, the idea that people with higher levels of education can learn from poor peasants with little or no formal education, is a major theme of the multiple source model.[27] Another major theme is that researchers in national and subnational systems are frequently the major innovators in the system, and as often as not, are transferring technology, knowledge and institutional innovations to centres as they are receiving useful inputs from above.

3. The Need for Prestige and Recognition

For scientists, it is not only a matter of access to resources to conduct research but also a matter of pay, promotions, status and influence within their discipline which affects their behaviour. Clearly it is not very sensible, if one is a bright, ambitious scientist, to get committed to an area of applied

research which is not popular amongst the providers of funds at a given point in time. The importance of the policy and political context regarding what areas of research are legitimate and might get funds, and has high or low prestige at a given point in time is well illustrated by the decisions of rice breeders in Asia. IRRI had a very major influence on many Asian rice breeding programmes to create rice varieties that yielded well under irrigationed high input conditions rather than resource-poor conditions. Scientists of equal talent who had skills in breeding for a wider range of more difficult rainfed conditions, have for many years received less funds, prestige and publicity. It was clearly the policy and political context rather than an academic scientific decision that had a major influence on which rice breeders were rewarded in their system.[28]

4. The Quest for Certainty in a World Which is Always Uncertain

A key feature of the central model is its implicit assertion that there is an ideal scientific system where knowledge is continuously collected, stored and systematically reviewed, and new directions for science come as a result of recognising gaps in knowledge. As new research is conducted, more information is accumulated at centres of scientific excellence and this reduces the chances that "mistakes" will be made in the future as a result of not enough basic and applied research having been done in the past. While at one level this argument is true, at another level it is clear that key scientific decisions are always made in a world of enormous uncertainty, and at best, research policy decisions are made on informed judgements - rather than certainties. The way arguments are presented, by whom, where and what resources are available to one scientific group rather than another, being as significant inputs to determining future research priorities, etc. as any arguments based on "gaps" in scientific knowledge. For those who believe in the central model this is a difficult concept to accept. For others who have no quest for certainty in this sense it is not

an issue. In the case of the Green Revolution in India, it is clear from an account by Hopper (1978) that the judgement by one group of pathologists and wheat breeders about the risks of genetic vulnerability by importing in India large scale quantities of Mexican wheat seeds, was taken rather from the judgement of another group of scientists who thought the risks were too high. In these issues there is no right or wrong answers. The risks of genetic vulnerability were dramatically demonstrated in 1978 in Pakistan when specific varieties of wheat were affected by rusts and wheat production dropped dramatically (Biggs & Clay, 1981).

5. The Ordinary Nature of Research

A further reason for the apparent paradox is concerned with the mundane and day-to-day nature of so much research. In many scientific communities there is an ethos that "research" is exciting and should be a free academic endeavour. It has nothing to do with the practical details of writing research proposals, keeping up with a minimum number of articles for publication in appropriate places, keeping up with progress reports, attending critical committee meetings, speaking out on controversial issues where one can never be "certain" about the consequences for one's career. The reality of research is that most of the work is often mundane, repetitive, hard work and the honours that flow may or may not be "justly allocated" - for one reason or another. A reason for the continued dominance of the central model is that it keeps attention away from these types of ordinary day-to-day factors that permeate research and have a major influence on the direction and content of research programmes.[29]

6. Monitoring and Evaluation

Another reason for the apparent paradox concerns the day-to-day administration of research and extension. On the one hand

scientists know that it is very hard to predict what will be the outcome of various avenues of research, what resources will be needed, etc. However, for administration and accounting reasons, they have to make proposals that often assert with great confidence that certain gaps in knowledge exist, and they will achieve definite outcome if they are given the money. During the research they have to submit accounts that show that funds were spent as they should have been. This creates a real dilemma: awareness of the uncertainties involved in doing research, but a recognition that proposals must be submitted in such a way as to attract funding. The central model, with its clear-cut definitions about how to define projects, what role different organisations play in the research and diffusion process etc., clearly fits better than the multiple model with the administrative and accounting requirements of government funding sources, the accounting procedures of aid donors, etc. The requirements that donor countries should see "value for money" also helps to promote the use of monitoring and evaluation methods that give a semblance of clear-cut, unambiguous analysis. One of the realities of all of this is that such methods are also helping to reinforce a central model approach to our understanding of agricultural research and diffusion systems.

There are also understandable tendencies for different interest groups to use monitoring methods to ascribe overall benefits to certain specific inputs when it was the combination of inputs which was the critical factor which gave rise to a "success", rather than any single input by itself. A research project which was "evaluated" by the spread of its technology, over a short-term finite period, may be ranked very differently if the evaluation criteria, instead, were more concerned with the contribution of the project to the development of a long-term local research capability. The resolution of this issue is very difficult. One of the reasons for the appeal of the central model is that it represents science in a clear-cut set of

activities that fits better with planning and monitoring techniques which use quantitative techniques for measuring inputs and outputs.[30]

7. Academic and Administrative Enclaves

A further reason for the paradox is because research and extension activities are frequently organised in formal institutions which are competing for scarce research or extension funds. Researchers on some occasions find it is in their own best interests to restrict the "open and free" flow of research information, in order to protect their position and access to specific sources of funds in a specific field.

The hierarchical bureaucracies of many research and extension systems in developing countries often encourage only a flow of information down the system, to the exclusion of methods for dialogue and cooperating between agencies at all levels, with the result that each agency is more or less an enclave. While in theory there are administrative mechanisms for interagency coordination, the reality is that few rewards are given and punishments may be administered for those personnel who do attempt to collaborate in the way the system suggests on paper.

8. Historical Analysis of Processes of Technology Generation And Diffusion

Another reason for the paradox is the training of scientists and type of literature available which analyses what factors interact and direct the R & D process at different points in time. It is rare, for example, for plant breeders, agricultural engineers and agricultural economists to have a significant part of their post-graduate training given over to work that gives systematic attention to politics, economics, the sociology of science, and the behaviour of large scale private and public research organisations. Most "training" in the understanding of these

phenomena is apprenticeship, on-the-job training at best and anecdotal at worse. Under these conditions, the central model with its great simplicity has great appeal, and is frequently adopted and defended.

IV. SIGNIFICANCE AND IMPLICATIONS OF THE MULTIPLE SOURCE MODEL

1. A Conceptual Framework

The significance of the multiple source of innovations model is that it places the dilemma of the ambiguous nature of the relationships between geographic space, time and institutions at the core of the analysis of the behaviour of research and extension systems.

In the multiple source model innovations come from anywhere in geographic space, from any research or extension institution, and from any instant in historical time. Whether innovations are recognised, attributed to one source rather than another, developed, used, transferred, adopted, promoted, smothered, rediscovered, ignored, or suppressed depends on the political, economic, technical and institutional context in which agricultural research and extension activities take place in time.

(a) Institutional Sources

The premise that innovations come from any institution implies that major and highly significant technology and institutional innovations can, and do, come from farmers' informal experimentation, from extension practitioners, from research practitioners (in national and international positions), and from research-minded administrators in large and small scale public and private enterprises.[31]

(b) Geographic Sources

One of the features that makes agricultural technology such an interesting area is that genes come from all over the world and unplanned mutations are always occurring in unpredictable ways. The advent of biotechnology has dramatically increased our awareness of the importance of the need to collect and develop legislation concerning the use of genes which have in the past, and are still coming from, multiple geographic sources.

(c) Sources Over Time

(i) Technology is defined by the historical context: It is in its approach to time that the multiple source model is most importantly different from the central model. The multiple source model accommodates the idea that there is no such thing as a unique classification of what is "a" technology, or what makes up a "modern" (or "advanced") or "traditional" technology. For example, and again turning to crop improvement, we could well say that the genes for grassy stunt resistance collected by scientists in India in 1966 were the most advanced technology available because it gave critical and significant genes to IR36. It was in part these genes that enabled IR36 to become the most widely grown rice variety emanating from formal research activities (Plucknett et al., 1987). In some sense, what a few years ago might have been labelled "traditional" technology and unimportant is suddenly labelled "modern" and "advanced" and seen as critically important.

(ii) What is important research is defined by the historical context: The second issue concerning time, is one relating to the recognition of innovations by formal science. The old saying of "being at the right place

at the right time" has particular significance for scientists and extension workers. For example, the innovative work by De (1939) on blue-green algae and its importance for increasing rice yields in Asia "lay on the shelf" from 1939 until the 1970s. This was partly due to the dominance of IRRI's influence on rice research and production strategies in Asia which argued that changing the rice plant in a specific way was the best way to increase rice production in Asia. While, recently, IRRI has adopted De's concerns and research, one might say he was a researcher who was ahead of his time and might have received research funds, prestige and been able to make an even greater contribution to science if he had been born a few years later.

(iii) The power of current interest groups defines what is known in science: The third issue of time concerns the selective use of earlier knowledge by existing interest groups. For many years poor households in developing countries have known they do not have a food storage problem. Yes, they have a food shortage problem, but storage difficulties are not generally part of this. Greeley (1986) has systematically documented the way experts and researchers from centres have been distributing and promoting selective information which justifies food storage research and development projects on the grounds that poor households have very high food storage losses, while in fact the losses in poor households are very low.[32] This illustrates a situation where facts were known by poor households for many years but this knowledge was not used to make informed scientific and development choices. By the same token, even now with the availability of the formal research by Greeley (1986) on crop storage, there are research and developed projects being put together as if the Greeley work does not exist.

(iv) Some rediscoveries of the wheel are new innovations: The fourth issue concerns the "re-discovering of the wheel". There are some types of innovations which are always going to be "rediscoveries" and are therefore "old" and "new" at the same time. This is especially true for institutional innovations concerning the way research is structured, organised and managed. There will always be ambiguities in this area. The recent interest in developing and promoting new on-farm and farming system research methods is a landscape of different actors discovering, rediscovering and labelling as "new" previously known approaches and techniques.[33] What is significant here is not so much whether something is in fact "new" (which is very difficult to track down) but to recognise that it is the actual use of the method or approach in a specific situation that is important and whether, and under what circumstances, the practice can be sustained over time. This depends, of course, on the political, economic, and institutional context of the research, and the ability of the researchers involved to be continuously innovative and find room to manoeuvre in that context.

2. The Language of Agricultural Research and Extension - A Need to be More Scientific and Precise[34]

(a) Transfer of Technology, Institutions and Knowledge - Which Way?

One of the most important implications of the multiple source model is for the use of language in research and extension. There are numerous ways in which terms used by the centre model would have to be dropped or changed if the multiple source model was to be used. Such terms as "transfer of technology" - which at the moment characterises so much of the thinking and practice of those using the central model, would have to be used more

precisely. For example, the term would not automatically be assumed to mean transfer of materials, methods, ideas, institutional innovations, etc., from laboratories to the farmer or from international centres to national systems. The term would be used in a neutral sense. For example, if one was interested in past transfers of technology from researchers to farmers and village level situations, one would analyse that flow of knowledge. On the other hand, if one was interested in analysing the flow of materials and knowledge from farmers and local informal R & D activities to extension agencies and researchers one would look at that flow within the overall research system. In a recent review it was found that very little serious analysis had been done on these multiple types of transfers of knowledge (Biggs and Farrington, 1989). In a recent study of on-farm research it was found that "feedback" from on-farm research to research station research policy was one of the weakest linkages in the on-farm programs (Merrill-Sands and McAllister, 1988).

The very terms "technology generation and diffusion" currently carries with it connotations of the central mode. However, the multiple source model sees a multitude of institutions which are generating and promoting technological and institutional innovations.

(b) Second Generation Problems

One of the ways that researchers who use the central model defend their position is to refer to some problems as "second generation". In this way it is implied that there are problems that have been encountered or caused by the transfer of technology or institutions from the centre which could not have been foreseen at an earlier date. This line of argument carries with it the notion that the centre was right in the past and although there have been some "second generation problems" they are dealing with them and they are still right. While there may

be some situations where this use of the term "second generation" is legitimate, a closer look at the historical record often reveals that there were "non centre" scientists who had at the time of the original decisions correctly predicted the outcomes and consequences of the proposed actions of the centre. However, the alternative actions they recommended to avoid future problems were generally ignored. One of the consequences of using the multiple source model is to recognise that it is the political context that determines which actors get listened to when science and technology decisions are taken. Portraying issues as "second generation" issues can be one of many ways of avoiding a recognition of fact[35].

(c) Productivity and Maintenance Research

In the central model, research is sometimes split into two types: 1) productivity increasing research and 2) maintenance research. The idea is that there is one type of research pushing towards increased yields and another for maintaining the gains already made. Often the first type of research is seen as more prestigious and important than the second. A major problem with dividing research in this way is that it can deflect attention away from critical and very difficult issues concerning the overall direction of science and technology, and the interrelated nature of the two types of research. What for some researchers may be seen as "productivity increasing" using one set of criteria, may be seen in a very different light by others who use different criteria for assessing progress in science. For example in the field of pest management, scientists who advocate the high use of chemical pesticides, see the need for substantial "maintenance" research to continuously find new pesticides as insects and other pest develop resistance to old pesticides. Advocates of integrated pest management strategies argue that this approach is misguides, high chemical input strategies often bringing with them far more problems in the short and long run than are solved. They point to a wide array of alternative

breeding, chemical and agronomy strategies underlying advances in science and technology. The increasing concern with the long term environmental effects of new technologies is also drawing attention to the need to question what criteria are used to define "productivity increasing" research. The multiple source model encourages us to search in many places for innovations and not treat productivity increasing and maintenance research as different areas of science.

(d) Adoption Studies

In the past adoption and constraint studies have often been restricted to analysing only the reasons why farmers do or do not adopt new technologies and methods coming from research centres. If the multiple source model is more widely used the scope of adoption and constraint studies will change significantly to include investigations on how and why research centres adopt or reject technology, methods, and ideas coming from researchers, extension agents, farmers and other actors in the agricultural research and diffusion system. With these changes researchers in centres might be very much more careful in the way they use such terms as adoption studies, as these studies will include analysis of their own behaviour[36]

(e) Outreach

Another term which would have to be redefined or dropped would be the term "outreach". At the moment it is generally used to denote projects and staff of "centres" who are seen in a helping role in developing countries. They are part of the transfer of materials and institutional capacity to conduct research. The major components of these projects are the staff employed. If the multiple source model is used then the national scientists from developing countries who are either on the staff of a "centre", or are there as a visitor, or there "for training" or

workshops, would be seen as performing an "outreach" function by transferring knowledge, materials and ideas from the various research and extension capabilities in developing countries in order to help centres adopt ideas and use certain materials and develop research capabilities.

(f) Demonstrations

In the past the word demonstration has been used to refer to demonstrating new technology or new methods to farmers or researchers at a lower level in the system. Often they have actually: (i) demonstrated what researchers or extension agencies do not know about relevant technologies for farmers or relevant research methods, or (ii) have been experiments (not demonstrations) which needed careful monitoring and assessment by researchers, farmers and extension agents alike.

(g) Farmer Field Days

In the past these have often been seen as ways of transferring knowledge and technology to farmers. In fact, some of the most significant outcomes of field days have been far different. On some occasions it has given farmers a rare opportunity to show and explain things to researchers, which had important long-term implications for plant breeding strategies in national and international centres.[37]

There are many other word and terms which, in one way or another have taken on very specific and narrowing meanings when used in the context of the central model. One of the implications of suing the multiple source model is that researchers will have to be very careful about the terms they sue in the future. They will also have to broaden the issues they study, unless they are to be held back within the confines of the central model.

3. Implications for Agricultural Research Policy

Some of the implications for research policy of the multiple model are:

(a) Global Research Policy: Multitude of International Centres

A major institutional implication of the multiple model is a recognition that there has always been a multitude of "international" centres. While the centres which come under the umbrella of the Consultative Group for International Agricultural Research (CGIAR) have had a high profile and excellent promotional facilities, there have always been other international agricultural research institutions. The Tropical Products Institute (TPI), which has now been incorporated into the Overseas Development Natural Resource Institute is a long-standing research organisation which has had an international mandate, as are CIRAD and ORSTOM, based in France, the International Agriculture Centre in Holland. The large scale multinational companies involved in research on, and promotion of, chemical agricultural inputs and agricultural engineering technology are another set of international centres with their own research, extension and promotion facilities. However, the implications of the multiple source model go further than just recognising a wide range of public and private R & D centres at the international level. It is a recognition that almost anywhere in the world is already or might become "the international centre" for certain research areas. For example, Bangladesh is probably the world's "international centre" for nematode research on rice. Whether this is recognised, funded or promoted depends on many factors.

Additionally, the multiple source model would see centres over time fluctuate between being a research centre and an information and exchange centre. It is quite possible that some of the current CGIAR institutions have been performing these fluctuating research and extension roles for many years. They may

increasingly play the extension and information exchange role as funds are allocated to strengthening research capabilities in developing countries.

The very fact that some of the most important developments in agricultural research in the past have come from national agricultural research programmes in Mexico, India and other developing countries adds weight to the view that there has always been a multitude of centres in national programmes which generated innovations as much as the international centres themselves. The fact that it has been presented in a different way reflects the political nature of research and the extent to which different groups of researchers respond to pressures impinging on their sphere of work.

The second issue relating to the international nature of science is a recognition that there have been many major differences between centres within the CGIAR system as far as their research strategies and behaviour are concerned. For example, the international potato research institute (CIP) has, since the early 1980s, promoted the view that farmer knowledge and informal R & D by farmers is as important a source of knowledge and innovations as some of the formal research work of the centre. The implications of the research policy of CIP was demonstrated by the composition of CIP staffing, the way interdisciplinary research thrusts were organised and managed, and the type of literature and self-image promoted by the institute. Other international centres have had different research policies and behaved in different ways. Some have now adopted parts of CIP's approaches.[38] One of the implications of the multiple model is that the policy and practice of each institution in the overall world research and promotion system has to be reviewed carefully to analyse what is happening in practice.

(b) Alternative Clients of Research and Diffusion Systems

In the central model "farmers" are at the end of the generation and transfer process and differences between farmers - if they are defined at all - being limited to those between "early adopters" and "others". Increasingly, some applied research programmers are classifying farmers by socio-economic criteria, such as their access to resources. In the central model differences between rich and poor farmers were often handled by such methods as incorporating in trials and demonstrations high, medium and low levels of management practice for rich, medium and poor farmers. This is only a modification of the central model approach. If the full political, economic and institutional implications of directing research and extension efforts to poorer groups is to be addressed then the central model is not a good starting point.

(c) Research Institutional Policy

In the past the central model has encouraged those involved with research policy to see analysis in this area as a matter of allocating funds between crops, between disciplines, between on-farm research and on-station research, between regions, etc.. Issues concerning human resources and the structure of the research and extension system have been passed to specialists in the area "organisation, management and training". Advice on these matters being sought from management specialists or from older, experienced researchers. In one way or another the central model proponents have down-played the policy issues of allocating and rewarding researchers to conduct different types of work and organise themselves in different ways. In fact, as the deployment of human resources is probably the most important of all research resource allocation decisions, it would appear that the central model has been able to shift the attention of policy analysis away from the most important of the research policy issues.

On the other hand, the multiple model takes one straight to this human resource research policy issue by analysing what political, institutional, or scientific criteria guide research promotions and the incomes of scientists. Are rewards to scientists guided by eg. length of service, by criteria which relate directly to declared development goals, or by criteria relating to some abstract notion of "good" academic research? The multiple model sees the sources and timing of funds (an institutional issue) as critical factors for understanding past and future research directions.

(d) Methods and Techniques

i) On-farm and Farming Systems Research Methods: In recent years a great deal of effort and attention has been given to the development and promotion of new techniques for on-farm and village level analysis.[39] What appears to be lacking from much of that work has been a serious consideration of the political, funding, economic policy and institutional context in which the methods have been developed, and the implications of this for the usefulness of the methods. It is as if those who have been involved in the work have proceeded with the idea that methods can be developed in a vacuum, or developed in one specific location and be easily transferred to another.

In many situations it has been found that cropping systems, non-farm and farming systems research methods have been introduced into research institutions with little prior institutional analysis. It appears to have come as a surprise that farming system researchers have often been marginalised. In addition, vast amounts of data from surveys and trials (some of which has sometimes been of dubious quality) has been collected by junior staff at the end of hierarchical,

centralised research and extension systems. Often the data was never analysed for the purpose it was collected. These issues should not have come as a surprise to the proponents of such techniques because the problems are the common and predictable outcomes of public and private sector organisational behaviour in all countries. They are problems which plant breeders, agronomists and other natural scientists are well aware of. They are issues which are well known to political scientists and students of public administration. The implications of the multiple source model is that researchers from the disciplines of political science, public administration, anthropology and rural sociology need to be involved in a significant way in the ongoing day-to-day work of international and national agricultural research and extension systems.[40]

Another implication emerging from many experiences is that the development and use of on-farm research methods is that their use is highly specific to the local political, funding, economic policy, and institutional context. This has resulted recently in a major change in approach by these groups. Instead of developing methods for the promotion of ideas and methods they are now emphasising the exchange of ideas and experiences between practising researchers in different locations. The multiple source model appears more useful than the central model. This is not an issue of evolution in approaches, as some critics of the central model have been advocating alternative approaches to institutional change for many years (Hart, 1961).

ii) Methods for Agricultural Research Policy Analysis

An implication of the multiple source model is that greater attention needs to be given to methods and techniques that can be used systematically to analyse the effects of different political, economic and institutional interest groups on the direction and content of agricultural research. Three tools which are useful in this context are (1) interest group determinant charts, (2) pay-off matrices, and (3) linkage analysis.

- Interest Group Determinant Chart

The first is the determinants chart as seen in Figure 5. This defines sets of interest groups which gain or lose from alternative research and extension strategies. What is significant about this type of analysis is that scientists in research institutions are seen as one of the active participants in the political arena which influence the direction of policies. It is also recognised that there are different groups of researchers who like to work on different things. This gives recognition to the fact that scientists are not, in any regard, "neutral" in their views and opinions on scientific and policy issues.

Another feature of this framework is that it is holistic and tries to incorporate all major factors that determine research and technological change. Some might ask, how the influence of different agrarian interest groups can be weighed against the influence of different donors or different groups of researchers. It is argued here that it is better to use such a qualitative tool as this with care, rather than avoid addressing these important but difficult issues, which are not readily addressed by quantitative methods such as rates of return on agricultural research

concentrating on narrow, specialised quantitative analysis which may have less utility for helping to understand past agricultural research policy or analyse what interest groups will try and direct changes in future policy.

- Pay-Off Matrixes

The second policy tool is the policy pay-off matrix.[41] This is illustrated by Figure 6. Basically, like determinant analysis, it identifies different interest groups who gain or lose from changes in research and extension policies.

Pluses and minuses are given to gainers and losers from changes in policies. It is a tool that helps to identify where and why there are common interests across research groups and economic actors. In Bangladesh the tool was used to help understand why so little R & D had been conducted on creating and improving irrigation technology that was relevant to declared national development goals. It was found that the strong local University of Engineering and Technology conducted little field research at the village and household level and, on the whole, was committed to teaching and research engineering which was more relevant to capital intensive situations, rather than relevant to the local field level circumstances. A change in the national irrigation policy towards irrigation technologies which were more appropriate to Bangladesh resource conditions could result eg. in changes in the staff structure and composition of research of the university. As in all university and research institutions there are strong vested interests which would lose from such changes. The dominance of specific interest groups in research institutions cannot be seen as outside the general political context of the country as a whole.

- Linkage and Functional Analysis

Linkage and functional analysis is used to provide a framework for looking at the linkages between different actors in research and extension systems. The boxes in Figure 7 represent the flow of information and technology, etc. between different actors in research and extension systems. What is useful about such a diagram is that it separates flows going in one direction from flows in the other direction. Strong and weak linkages can be illustrated by pluses and minuses. Once strong or weak linkages have been identified, the political, economic and institutional reasons for this can be investigated.

Once again, while this is a qualitative tool, it is helpful for identifying major issues which affect the behaviour of research and extension institutions.. Linkage and functional analyses have been two of the major research methods used in a recent study of on-farm research in nine developing countries (Merrill-Sands et al., 1986).

V. CONCLUSIONS

It could be argued that the greater interest on the part of some international funders of research in strengthening national and regional research systems, there is a gradual evolution of the central source model of the 1970s and 1980s towards a multiple source model suitable for the 1990s. Whether this is true or not will be reflected by the language and actions of researchers in international and national agricultural research and extension systems and the way research funders actually allocate their resources.

The two models have very different perspectives of the structure and behaviour of agricultural research and technology promotion systems. There will be powerful political, economic and scientific interest groups who will be arguing for alternative paths for research and technology promotion systems in the future. As in the past, there will be continuous disequilibrium in the system and there will be gainers and losers.

Perhaps the key indicator of whether there is a significant shift towards a multiple source model, is whether researchers and funders allocate substantial research resources to strengthen the capability of poorer groups in rural areas of developing countries to exert more effective direct control over the content and composition of international and national research and technology promotion systems.

It is hoped that the multiple source model will help focus attention on some of the continuous conflicts and trade-offs in science, rather than pushing these issues into the background as if research, in any meaningful way, can be separated from the historical, political, economic and institutional context in which it takes place.

ENDNOTES

1. For recent expressions of this view see Levi's mango thesis. He sees technology like the stone of a mango. It is not a shiny, clean stone separate from the flesh of the mango, it is a fibrous stone which merges into the flesh of the fruit (Anderson et al. (1982), Anderson et al. (1988). Clark (1987) argues in a similar way, that science cannot be viewed independently from current economic and political events.

2. In this paper the words "scientist" and "researcher" are used interchangeably, and unless otherwise specified, social scientists and natural scientists are not treated separately.

3. For a review of alternative models of research and diffusion, see Biggs and Clay (1987) and Biggs and Farrington (1989). Everett Rogers in his early work on diffusion, used a central-periphery model. In recent years he has rejected that model and proposes a model where innovations come from decentralised sources (Rogers, 1983). Many of the criticisms of the "transfer of technology" model of agricultural research by Chambers and Ghildyal (1985) and others working in farming systems research, focus on restrictive characteristics of the dominant central-periphery models of science.

4. This model is often called by such names such as the transfer of technology model, the bridge of agricultural research and extension model, and the lab-to-land model.

5. For a recent excellent account of international germplasm networks see Plucknett et al. (1987). One of the gaps found in a recent review of social science analysis in agricultural research, was a lack of systematic analysis of the purposes, outcomes and cost-effectiveness of research networks (Biggs and Farrington, 1989). They are generally considered to be a "good thing", but in many contexts suffer from fluctuating interest on the part of funders. Networks, like other institutions for the transfer of knowledge and materials, can be controlled and directed to benefit a variety of interest groups.

6. For a description of several institutional models developed in this style and orientation see Whyte and Boynton (1983). For a description of the Comilla model and how it fared when transferred to 20 thanas in the Comilla district see Khan (1971). Subsequent events have been described by Khan (1979) and Blair (1985). Two of the major reasons for the decline of the Academy as a research institution was its inability to learn from institutional innovations coming up from multiple sources in rural areas, and its inability to adopt a flexible, dynamic research programme in response to the changing political, economic and institutional environment (Biggs, 1979).

7. For example, some international agricultural research centres and U.S. universities were seen as developing farming systems research methods as "packages for easy deliver...to LDC institutions" (Shaner et al., 1982, p.xv). In its early years IRRI's economic programme proposed fairly standardized methods for conducting constraints research in Asian countries. The cropping system's methods proposed by IRRI have slowly become more flexible as the methodology has adopted innovations and advice from national research. systems and farmers. For a review of the innovations of this central approach in farming systems research see Biggs (1985), and Heinemann and Biggs (1985).

8. For a presentation of this view see Hayami and Ruttan (1973).

9. For a description of the T & V system see Benor and Baxter (1984). For a review of how it works in practice, see Howell (1988) and Moore (1984).

10. The issue of technology and institutional definitions is central to problems of separability and aggregation. Two objects that might be classified in one way by one criterion may be classified differently by other criteria. Two items that might be classified as the same at one level of aggregation may be classified separately at a lower level. The need to analyse technology as its component parts, rather than as its developed (packaged) form is argued by Clark (1987).

11. Informal research describes the omnipresent informal experimentation, plant selection and other research activities of "research minded" farmers which taking place

in all agrarian societies (Biggs and Clay, 1981), Biggs (1980), Brammer (1980), and Rhoades (1988). For a collection of studies in this area see Pacey et al. (1989), Farrington and Martin (1987), Brokensha et al. (1980), Richards (1985), Farrington (1988), and Chambers and Howes (1979).

12. For a discussion of formal and informal research, and a review of the strengths and weaknesses of informal systems, see Biggs and Clay (1981), and Biggs and Rood (1988).

13. For a recent review of the diversity of agricultural research institutions see Biggs and Farrington (1989). Increasingly, the diversity of extension systems is also being recognized (Rivera and Schram (1987), Thiele, Davies and Farrington (1988)).

14. See Sagar and Farrington (1988). They describe, amongst other things, the work in reports by Bunch (1985 and 1987).. Anderson et al. (1988) give many examples of what they call "lateral" flows of technology.

15. For example, see Binswanger (1978), McInerney and Donaldson (1975) and Burch (1980).

16. Perhaps one of the best known examples of institutional innovative research and promotion is that of the Grameen Bank in Bangladesh. Dr. Yunus, a highly trained economist and Head of the Economics Department of Chittagong University, started in the early 1970s to experiment in an action research project with institutional structure to provide credit and savings services to landless men and women in rural Bangladesh. From the start and throughout the continuously changing process of institutional development, the "research" took place in the real world of Bangladesh and not in a scientific or social science laboratory. For an analysis of the institutional innovating process of the Grameen Bank and several agricultural researchers who developed their own field level methods and locally viable institutional structures, see Biggs (1984). A recent report on the Grameen Bank has been written by Hossain (1988).

17. The important role of use innovations in industry has been analysed extensively by Bell (1986) and their significance of industrial experiences for agricultural and rural research systems discussed recently by Gamser (1988). Different writers have noted this type of source of innovation. For example, lateral sources (Anderson et al., 1988), horizontal sources (Biggs, 1986), and decentralised sources (Rogers, 1983).

18. For details see Biggs (1989) and Merrill-Sands and McAllister (1988), Ewell (1988, in preparation), and other reports from the ISNAR client orientated on-farm research (OFCOR) study.

19. Good examples of these innovations are given by Thiele, Davies and Farrington (1988). In Bangladesh the Mennonite Central Committee, a large NGO, has been working as part of the national farming systems network for many years (Jabbar and Abedin, 1987). In Guatemala there is high integration between a large national NGO and the Ministry of Agriculture (Gutierrez, 1988).

20. For a review of literature which includes coverage of private sector activities see Biggs and Clay (1987), and Biggs and Farrington (1989). Pray (1983) discusses some of the benefits of encouraging private sector agriculture R & D in Asia. Policy analysis regarding patents and the way benefits are distributed from private sector agricultural R & D is a topic which has been neglected in the past (Evenson, Evenson, Putman (1987), Biggs and Farrington (1989).

21. For a discussion of rent seeking activities in a contemporary developed context, see Toye (1987).

22. Accounts which are critical of the involvement and influence of donors on research directions are Anderson et al. (1988) and Jennings (1988). A view which is not critical of the donor's major involvement is given by Lele and Goldsmith (1986).

23. These are discussed in Clay and Schaffer (1984) and Leonard (1987). Burmeister (1987, 1988) shows how concerns of planners in the administration, rather than the advice of scientists or the problems of farmers were major factors that determined the science and technology policies in Korea in the 1970s. In Bangladesh in the 1970s the Planning Commission's perspectives of the technical and economic issues of increasing rice production dominated over the views of local rice breeders (Anderson et al., 1988).

24. In some recent analyses of the decline of British science it is shown that reduced research budgets explains the declining performance of British Science at the international level as measured by publication and citation indicators (Irvine, Martin, Peacock and Turner, 1985).

25. The countries were Guatemala, Ecuador, Panama, Senegal, Zambia, Zimbabwe, Nepal, Bangladesh and Indonesia. There are case studies for each country. The comparative papers include ones by Ewell (1988, forthcoming), Merrill-Sands and McAllister (1989), Biggs (1989), and Bingen and Poats (forthcoming).

26. The myth of the neutrality of science, which the central model helps to promote, has been addressed by several writers (eg. Koppel and Oasa, 1987, Burmeister, 1987, Anderson et al., 1982, and Anderson et al., 1988).

27. Chambers takes up this position in many of his writings and suggests that "reversals" of roles between poor peasants and researchers would result in improved scientific practices (eg. Chambers, 1980).

28. See Hargrove's reports (1977 and 1979) on a survey of rice breeders in Asia. These early science policy decisions were often challenged at the time (for example, in Bangladesh and Sri Lanka (Anderson et al., 1988) and have been challenged continuously. This has been partly on the recognition of a need for location specific varieties (Evenson, 1974; Farmer, 1979). Also on the grounds that the pay-offs to a broader strategy which allocated more funds to rainfed conditions would be higher than the narrower strategies (Barker, 1981). Recently, scientists such as Dr. Maurya, who have been working on these more difficult problems for many years, are getting increased international recognition (Maurya et al., 1988).

29. Aronowitz (1988) argues that the separation of "science" and "technology" is a way of denying the influence of real world value judgements, on what scientists do. The importance of the real world day-to-day environment of scientists is also argued by Latour (1979) and Feyereband (1975).

30. In some ways the misuse of rates of return analysis is an example of the way quantitative monitoring and evaluation can obscure rather than help our understanding of the way research systems work. There are many studies conducted on the rates of return to public sector research. Ruttan (1982) lists many of these. While this type of work has helped illuminate some issues as regards the inputs and outputs of research investment decisions, it has also helped contribute to the paradox of the domination of the central model.

There are at least four ways that rates of return analysis has done this:

(1) The period of time over which the inputs and outputs of research are recorded. In any rates of return analysis one has to decide on a finite starting date and finite ending date for the analysis. This gives the impression that such things are unambiguous and easy to define. However, if we think back to the diagram of the multiple source model, it is clear that all research institutions and efforts have a history. At which point in time do you start counting "the cost" of research? The rates of return to research can vary on the way inputs from the past were weighted.

(2) The second problem arises from the difficulty of identifying which research activities (in the time period chosen) to attribute the benefits of research. While informal farmer adaptive research is a major type of research in most developed countries, and often a crucial research activity for the diffusion of technologies from formal research institutions, it rarely gets explicit recognition in the rates of return analysis. Bell (1986) has shown that by recognizing and allocating some returns to informal R & D by farmers, estimates of return to formal R & D are significantly reduced. In a rates of return analysis of on-farm research in Panama (Martinez and Sain, 1983), the inputs of the international centre involved were not included, although they were substantial (personal communication from P. Ewell).

(3) The final problem arises from the fact that often rates of return figures are presented without reference to the political, economic and institutional context which helped

give rise to the rates of return. This gives the impression that when there have been high rates of return that investments in research were in a sense independent of these contextual issues. However, investments in research are, like any other investment, dependent upon such features as effective demand for the products of the investment. If the price of a crop in which research investments had been made declined over a specific period, their returns would be different from a situation where prices increased. If government policy had influenced price increases or decreases over that period then one is measuring, in effect, returns to decision-making in price policy as much as returns to decision-making in research policy.

(4) The fourth reason for a problem with the misuse of rates of return figures is that they are used in the political process of actors trying to get funds for research. The estimated high rates of return figures generated in the past have been used as an argument for why research should get funds in the future. Critics of the rates of return analysis who have said that the analysis has its shortcomings, or that returns may be lower than claimed, have been accused of not defining science from those interest groups who want to reduce public sector funding of research. This was one of the arguments levelled at the work of Harvey (1988) who has been working with one of the panels of the British Agricultural Research Council in recent years.

31. For example, see the multiple sources of innovations from institutions with different designated roles, in Rogers (1983), who describes examples from North America and China.

32. Greeley's own empirical research in Bangladesh involved a very large, carefully conducted survey by crop storage specialists, and show, at least for Bangladesh, that the food storage losses in poor households is very low.

33. Many of the objectives and practices of exploratory surveys, reconnaissance surveys, key informant surveys, rapid rural appraisal surveys, rush report surveys, and task force surveys are very similar. Frequently the surveys come into existence as a result of the original thinking and practice of research practitioners or administrative practitioners who are getting on with the job of work. Some of their features have a lot in common with what students of public administration would recognize as trip reports which are standard practice in civil service cadres, and frequently used by large private and public sector organisations.

34. For a broader and more general discussion of the importance of language and labelling in development dialogue, see Clay and Schaffer (1984), Wood (1985), and Harvey et al. (1979).

35. This is well illustrated by debates surrounding the decision to transfer the institution of the Land Grant College of research/extension/teaching from the United States to India and Bangladesh. Some of the problems of such an approach are well documented by Hart (1961), Hunter (1969) and Brass (1982). In the case of green revolution technology, problems over the low generation of employment and therefore of effective demand for food in rural areas were identified at an early stage in the green revolution strategy (Falcon, 1970; Rudra, 1988). However, Dandekar (1986) reports that few changes were made to technology and development policy to increase rural employment. As regards rice plant breeding, the need for location-specific varieties and strong local breeding capabilities were identified by many writers at an early date in efforts to improve food crop yields (Farmer, 1979; Evenson, 1974). In some national research programmes in Asia, breeding programmes were often already in place that took account of the diversity of agro-climatic conditions. In the case of Sri Lanka and Bangladesh, these strategies were put under great pressure or replaced by programmes to develop widely adaptable rice varieties for resource rich conditions, as promoted by the International Rice Research Institute. The lack of spread of these widely adaptable varieties did not come as a surprise to the local breeders who had argued for alternative strategies for increasing agricultural productivity (Anderson, Levi, Morrison, 1988; Pain, 1986). For them these outcomes were not a "second generation" problem.

36. Lawrence Busch (1978) in a view of adoption research compares and contrasts adoption research with an alternative approach, which has some similar themes to the multiple source model discussed here.

37. For example, see the outcome of some farmer field days in an on-farm tricale programme in North India (Biggs, 1982, Chauhan, 1980).

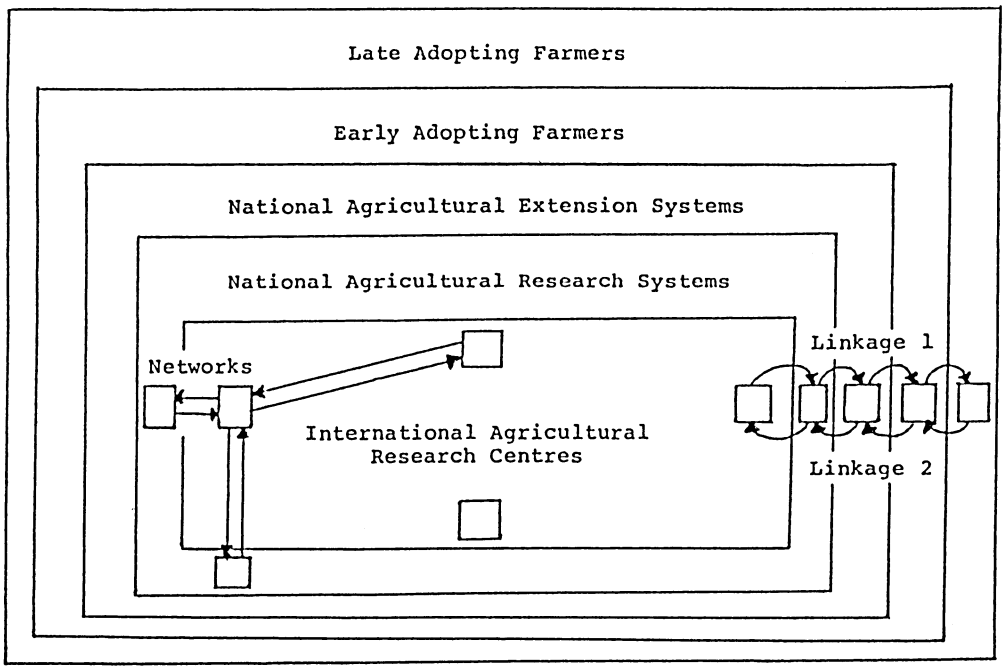
38. See one of the CIP circulars on this subject (CIP, 1981).

39. For example, see the voluminous literature on farming systems and on-farm research.

40. This means the involvement of researchers well trained and experienced in their disciplines. It is not being suggested here that agricultural economists or professionals any other discipline create, under their own umbrellas, a subset of professionals in their disciplines to look at these issues. Only too often this type of institutional response results in avoidance of addressing fundamental issues.

41. For the use of pay-off matrices in the analysis of technology policy situations see Biggs (1978), Stewart (1987) and Chambers (1978).

Figure 1: Institutions of a Central Source of Innovation Model of Agricultural Research and Technology Promotion



Linkage 1 = Transfer of technology

Linkage 2 = Feedback linkage

Networks = Exchanges of germplasm, other technology and information

Figure 2: Hierarchical Structure of the Central Source of Innovation Model

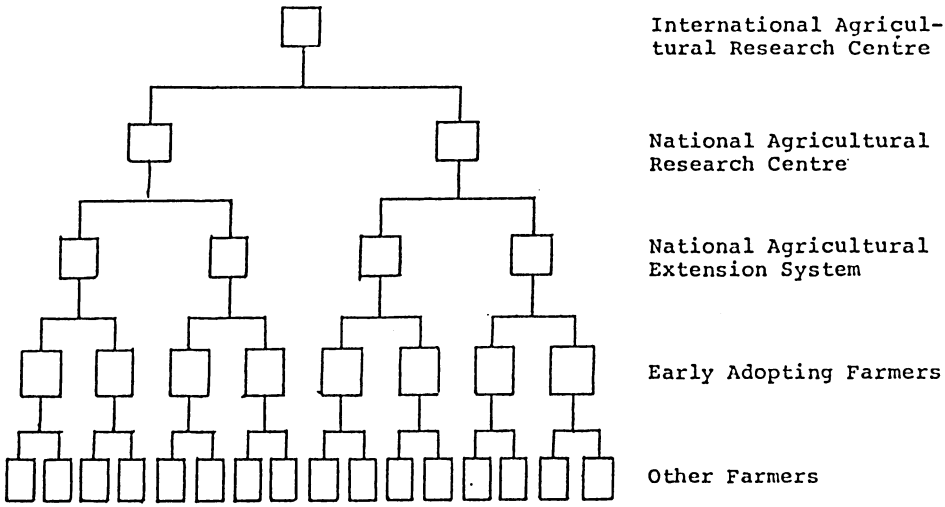
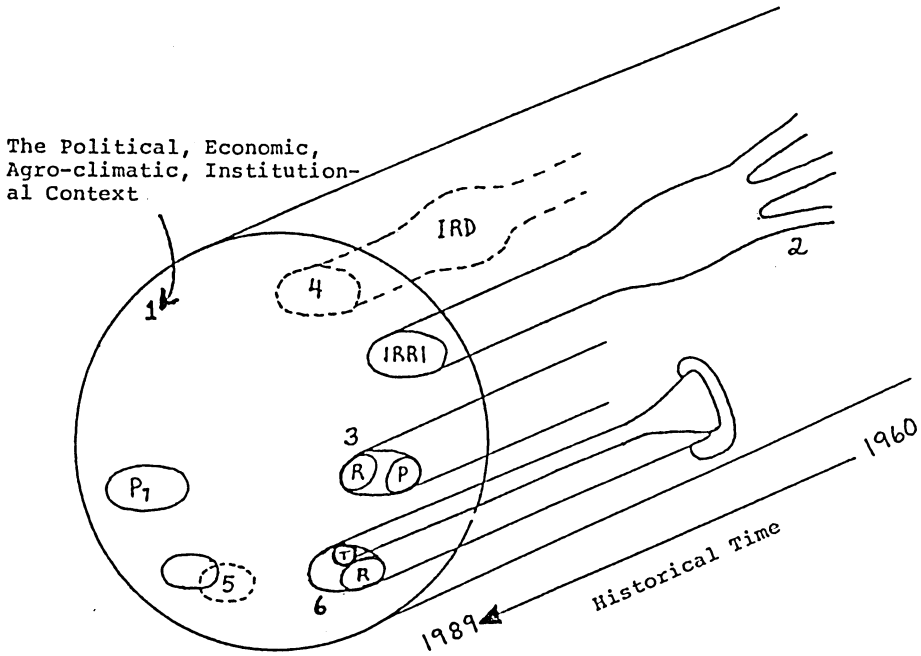


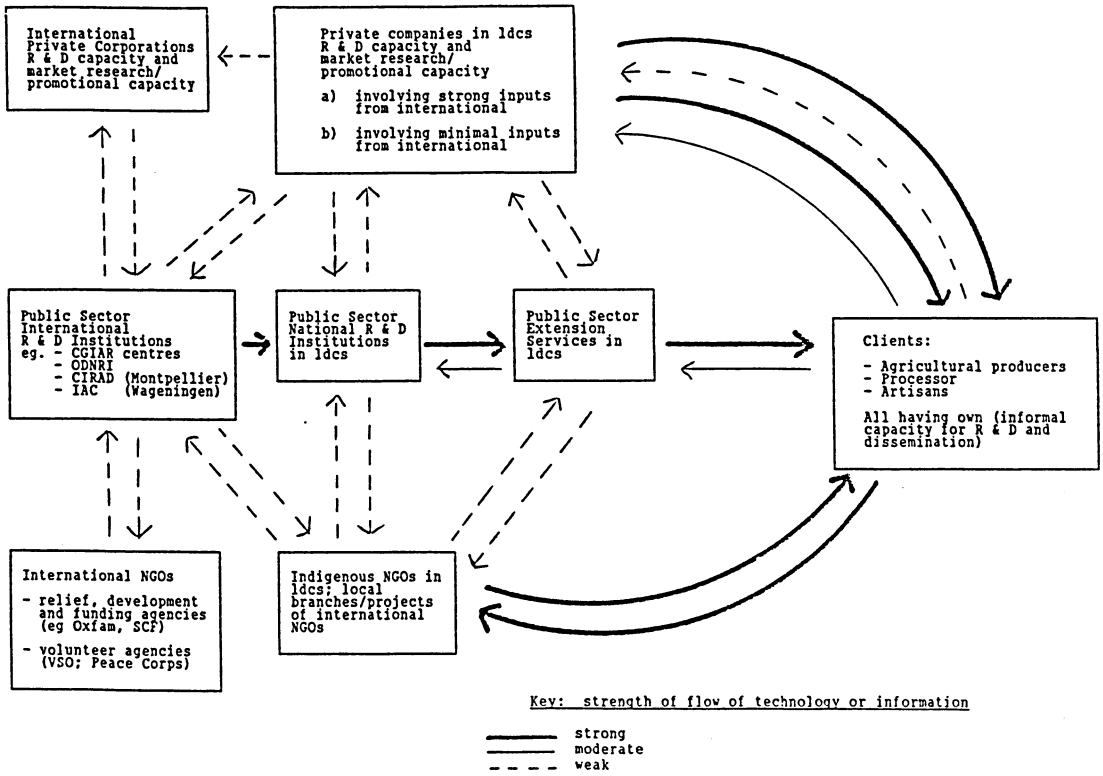
Figure 3: Multiple Sources of Innovation Model of Agricultural Research and Technology Promotion



○ = Formal (institutionalised) research (R), promotion (P), and training (T) capabilities. These may be in the public sector, the private corporation sector, or non-government organisation (NGO) sector.

◌ = Informal research and diffusion (IRD) capability.

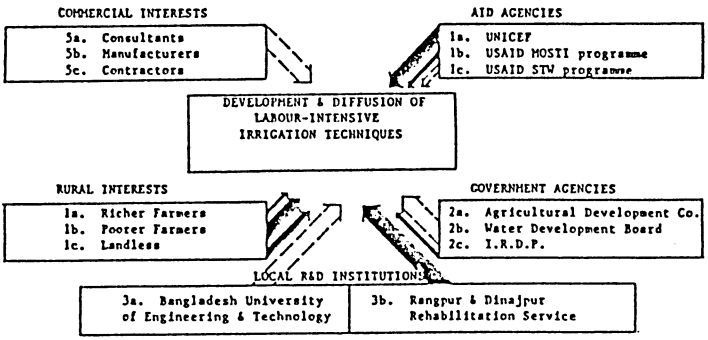
FIGURE 4: General typology of agricultural research, by interaction among institutions



NOTE: In principle, interactions could be identified among all the research and extension boxes on the diagram. However, to inset arrows indicating these would make the figure complicated. It should be noted that when a research manager is selecting potential social science research he/she should consider all possible linkages. (See Chapter 5).

SOURCE: Biggs and Farrington. 1989. "Agricultural Research: A Review of Social Science Analysis" (draft)

Figure 5: Interest Groups Determinants Chart for Irrigation Research and Promotion Policies in Bangladesh



Note: The width of the arrow indicates the relative strength of a specific institution or interest group. A positive influence is shown by a solid arrow and a negative influence is shown by a broken arrow.

Source: Biggs, S.D. and Griffith, J. 1987. "Irrigation in Bangladesh" in F. Stewart (ed), Macro Policies for Appropriate Technology in Developing Countries. Westview Press, Boulder, Colorado, pp. 74-94.

Figure 6: Pay-off Matric for the Analysis of Irrigation Research and Technology Promotion Policy in Bangladesh

Interest Groups	Distribution of Benefits	
	Mechanized Irrigation	Manual Irrigation
1. International Aid Agencies	++	--
2. Irrigation Departments	+++	-
3a. Mechanized R&D projects	+++	---
3b. Appropriate R&D projects	---	+++
4a. Large Peasants	+++	-
4b. Small Peasants	-	+++
4c. Landless Peasants	+	+++
4d. Rural Artisans/Workshops	+	+++
5a. Installation Contractors	+++	---
5b. Equipment Manufacturers	+++	---

Note: Positive benefits = +
Negative benefits = -

Source: Biggs, S.D. and Griffith, J. 1987. "Irrigation in Bangladesh", in F. Stewart (ed), Macro Policies for Appropriate Technology in Developing Countires. Westview Press, Boulder, Colorado, pp. 74-94.

Figure 7: Linkages for the Flow of Information, Technology, Innovations, Knowledge, etc. in Global Agricultural Research and Promotion Systems

Groups sending information, technology, innovations, knowledge, etc.	Groups receiving information, technology, innovations, knowledge, etc.								
	1	2	3	4	5	6	7	8	9
	Farmers								
	Resource Rich	Resource Poor	Farmer Experimenters (Informal R&D)	Extention Institutions	On-Farm Research Institutions	Experiment Stations and Research	University Teaching Programs	Govt. Dev. Policy	Policies of Centres Intern. Agric. Research
Farmers 1. Resource-rich									
2. Resource-poor									
3. Farmer Experimenters (Informal R&D)									
4. Extension Institutions									
5. On-farm Research Institutions									
6. Experiment Stations and Research Policy									
7. University Teaching Programs									
8. Government Dev. Policy									
9. Policies of Centres of Intern. Agric. Research									

Source: Adapted from Merill-Sands, D., S.D. Biggs, S Kean, J. McAllister, S. Poats, E. Moscardi and S. Ruando, 1986. Guidelines for the Analysis of Linkage and Information Flow ISNAR Study on the Organization and Management of On-farm Research in NARS, ISNAR, The Hague.

Table 1: Characteristics in Alternative Models of Agricultural Research and Technology Promotion

Characteristics/Topic	Central Source of Innovation	Multiple Source of Innovation
	Emphasis given in the model	
1. DEFINITION AND ROLE OF INSTITUTIONS	Institutions clearly defined by (1) International, National and Regional Status, (2) research or extension role, (3) Sometimes a crop or technology mandate	Ambiguous as regards playing an international or national role and performing research or extension functions
2. STAGES IN TECHNOLOGY RESEARCH, EXTENSION, AND ADOPTION	Emphasis on a linear sequential path of stages in technology generation, adaptation and demonstration (a problem solving approach)	Emphasis on continuous interaction between researchers, users, extension agencies and continual assessment of the political, economic, technology and institutional environment
3. STAGES IN RESEARCH CAPABILITY DEVELOPMENT	Emphasis on the transfer of research capability from outside	Recognition of the prior existence of local R&D and diffusion capabilities and how outside interaction selectively strengthens, weakens, and improves parts of this
4. STRUCTURE OF RESEARCH AND EXTENSION SYSTEM	Hierarchical and centralised. A few standardized research and extension institutions	Uniform/lateral/horizontal/ decentralised. A multitude of diverse research and promotion institutions
5. NETWORKS FOR MATERIALS AND INFORMATION FLOWS	Networks. Coordination of information and technology in networks is systematically performed according to unambiguous criteria	Access to and control over information and materials in networks is selective and determined by the interests of different scientific, political, economic and administrataive interest groups
6. USE OF DATA AND KNOWLEDGE OVER TIME	Assumes the systematic accumulation storage and use of knowledge	Assumes selective accumulation and selective use of knowledge over time

7. TREATMENT OF TIME	Minor consideration: a "timeless" model in which knowledge is systematically accumulated and always used for informed research policy decisions	Critical feature: Whose knowledge counts, and who controls research funds determines the direction and content of research, and who gets the benefits at any point in time
8. DEFINITION OF TECHNOLOGY	Frequently in broad unambiguous terms such as packages of technology or "how to do it" manuals. Definitions and specialisations of science dominate over definitions and categorisations of users	Emphasis on components (whether materials, methods or institutions) which are combined locally. Definitions and categorisation of science and users given equal importance
9. SOURCES OF INNOVATIONS	(a) Central Sources: Major emphasis given to innovations coming from formal designated research institutions which are transfered to promotion and institution users (b) Little emphasis on the unpredictable nature of innovations (c) Institutional innovations can be created and developed and transfered from centres to lower levels in the system	(a) Multiple Sources: Equal emphasis given to informal research by farmers and other users, innovations by local research practitioners, research minded extension agencies, administrators, and others in real world situations as to innovations from designated central research institutions (b) Major emphasis on unpredictable sources of innovation (c) Institutional innovations are, in a sense, always new and their use depends upon the specific political, economic, technological and historical context in which they are used and sustained
10. POLITICAL FUNDING AND INSTITUTIONAL CONTEXT	No or little emphasis in the model. The direction of science is seen as (or should be) independent of political and other contextual issues	Central to the Model. The level and source of funding determines the direction and context of research

11. CENTRAL/REGIONAL ALLOCATION OF RESEARCH RESOURCES	Debate is primarily based on agro-climatic and technical economies of scale in research arguments (e.g. by geographically defined regions, zones and farming systems). Pattern of resources between central and regional stations. Primarily based on the need for regional staticns in different agro-climatic regions to service central stations or centrally controlled research policy	Debate primarily based on political, economic and institutional issues as well as to agro-climatic and economies of scale in research arguments. Pattern of regional resource allocation based primarily on the need for strong regional stations with power to influence the research policy of central stations, and be able to effectively use other research institutions
12. ORIENTATION	"Supply push" with centres generating and promoting good technology	Political economy factors determine the availability of research funds for different purposes. Proponents of poverty reduction R&D place emphasis on giving resource-poor clients the ability to effectively demand R&D on their problems
13. DYNAMICS OF THE INSTITUTIONS IN THE R&D SYSTEM	There is a "natural progression" in the development of research and extension institutions	A system of institutions which are always in disequilibrium and undergoing major structural change
14. REWARDS TO RESEARCHERS AND TO RESEARCH AND EXTENSION INSTITUTIONS	Returns to research ability and contributions to a "good" science and extension work	Multiple Criteria, e.g. (1) Returns to rent seeking activities; (2) Returns to profit motives; (3) Returns to good science; (4) Returns to administrative activities; (5) Returns to serendipity
15. DETERMINANTS OF THE BEHAVIOUR OF RESEARCH AND EXTENSION INSTITUTIONS	Mainly directed by the logic of stages in a scientific problem solving cycle, e.g.: (1) Stages in a problem-solving process; (2) The role an institution is designated to play in stages of technology generation and diffusion; (3) The stage of a country's research and extension's capability development	Mainly directed by specific political, economic and institutional forces, e.g.: (1) Access to different types of research and extension resources; (2) Political power of governments to pass and implement legislation relating to the flow and use of technology; (3) Strength of different socio-economic and other interest groups to make demands on research and extension systems;

15. DETERMINANTS OF THE BEHAVIOR OF RESEARCH AND EXTENSION INSTITUTIONS (continued)

(4) Ability of research and extension institutions to create enclaves around their institutional activities; (5) Dynamics of internal politics of research and extension institutions; (6) Access to ideas, technology, methods etc. that can be gathered and used

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