Chapter Three

Literature Review

Introduction

A range of development efforts have been attempted in the past four decades. In the 1950s and early 1960s the major theme was industrial development. In the mid-1960s, the dominant interest of donors switched to agriculture. Thus, in the early 1950s and 1960s, the dominant concern in developing countries was to establish formal agricultural research and extension systems. This focus emphasised higher-level agricultural education closely integrated with agricultural research and extension work, strengthening research institutions created during the colonial period, and establishing international agricultural research institutes.

The development thinking and policy practice thus focused upon dramatic "modernization". Science policy-makers sought to by-pass the slow process of establishing agricultural research outfits through large scale transfer of technology and institutional models for technology generation (Ruttan, 1975). To deal with the problems of the poor and their neglected food crops, the international response was the creation of international agricultural research centre and institute representing the single most important effort in development of national agricultural research programmes in developing countries. The institutional model had a wide range of consequences and generated considerable controversy reflected in the growing body of literature on technical change and science policy, the role of formal science and technology in the generation and diffusion of technologies for Third World agriculture.

This literature is diverse, and represents the preoccupations of different writers. For example, anthropologists and sociologists are preoccupied with the impact of communication and socio-cultural factors, resistance to innovation, diffusion overtime and space (Rodgers, et al, 1976). Economists have focused primarily on the effects of economic variables such as profitability of the innovation, at a macro and micro levels (Zvi Griliches, 1959; Mansfield, 1968) while geographers and environmentalists focus on the relationship of science and development in the context of environmental science and prospects for increased production, and on ecological crisis in a spatial context (Paul Richard, 1985).

There is also a body of literature on induced innovation concerned with relationships of factor endowments and changing relative prices (Hayami and Ruttan, 1971). More recently there have emerged concerns with the feedback effects of technology diffusion on trade relationships (L. G. Reynolds, 1975).

There are substantial differences among these disciplines. What is important is that these preoccupations all represent responses to modernisation of agriculture in Third World countries through transfer of agricultural technology.

This chapter explores the literature on modernization of agriculture in developing countries, examine the international transfer of agriculture technology, and review the theory of technical change in agriculture and research policy.

Modernization of Agriculture: Some Reflections

Development literature contains a dozen or so models of early economic growth. Agricultural science in development mainly focused on modernization. Policy practices were also based on Western capitalist agricultural development experience. From a conceptual point of view, development in developing countries seemed easy, for it entailed using capital and technology. Modern sector would gradually expand, transform and absorb the larger traditional sector. This assumption, gave no thought to the actual situation, historical realities, economic systems, or values of peasants in rural areas in most of the Third World countries.

This model of development has also given rise to the analysis of scarcity according to the west. It has been assumed, for example, that developing countries must adopt the same capital intensive technologies that predominate in the industrialized countries. However, even in these countries, with a high rate of multiplication of capital and a low rate of population growth, it is not easy to maintain full employment. For most Third World countries, with a low rate of capital accumulation and high rate of population growth and where the majority (60-80 percent of the population) earn their living in the tradition setting, the problem is more complex.

It has also been assumed that technology originally developed for demands in the modern sector should be easily and equally adopted by people in the traditional sector. The conviction has been that rural life will improve if the rural people adopt new technology (Ascroft and Gleason, 1981). This raises three questions. The first relates to whether relevant technology exists for the rural people. The second question concerns the relevance of international agricultural technology and institutions and third is on the way suitable technology can be transferred to the majority of the producers who also are the main consumers.

Increased food production has long been the major objective of agricultural development in developing countries. Initially, this led to the creation of the United Nations Food and Agriculture Organization (FAO) in 1945. FAO later started its Freedom from Hunger campaign. At the time, there was belief that food could be produced in sufficient quantities. A few years later, high yielding rice and wheat cultivars appeared and were put into use in Third World countries, which led to further optimism (e.g. Brown, 1970). In spite of the optimism, there has been an important period of questioning and redefining the model and the role of agricultural science and technology in development after the experience of the Green Revolution in Asia in the mid 1960s (Griffin, 1974; George, 1976; Lapple and Collins, 1978). In contrast to conventional analysis, George (1976) points out that solutions to the world hunger are not to be found as technical aspects of new farming techniques and new methods of birth control. Instead, they depend foremost on social and economic changes such as access to productive resources by the majority of producers. The same thinking is documented by Lappe and Collins (1978). They argue that hunger is not caused by scarcity but through the increasing concentration of control over food producing resources. Similarly Amartya Sen (1981) shows that malnutrition is much less the result of food grown, and much more the result of poor people lacking the means to obtain it. In short, the problem is one of poverty rather one of food supply.

A range of development efforts have been attempted in the past decades. Central to the range of development efforts has been institutions building so as to facilitate the rapid transformation process and new and improved technology. In this transformation process it was assumed that formal research and extension institutions and technology could be transferred to Third World agriculture to facilitate the development process. Generally, past efforts in modernization of agriculture in Third World countries have been frustrating and progress has been slow. This raises the question whether past and present development effortshave been appropriate.

In the recent past, this concern has mounted, leading to arguments for an alternative development model or for ways to generate and diffuse technologies. Martin Bell (1985), after reviewing the past experience and efforts of Third World countries in harnessing science and technology for development, states that the efforts failed not just because the application of technology had moved at a rate that was inadequate to make a significant dent in the problems of poverty but because its direction led Third World countries, especially the smaller and poorer ones, into a blind alley. The pursuit of development on the basis of costly, resource-intensive and import-intensive technology has generated increased wealth, but only for a few; it has also led to massive indebtedness, environmental degradation and in some countries, extreme socio-economic vulnerability and instability. He goes on to point out that what is needed is not just a greater development effort but a different kind of effort. Development strategies need to focus on the majority of the people living in rural areas, on meeting their basic needs food, shelter, clothing and health, and on patterns of economic growth that can be sustained without imposing destructive stress on society and the natural environment. Also efforts to harness science and technology to development need to move in a new direction not just towards the increased production of odd items of appropriate technology but towards a much more pervasive shift that will underpin a totally different pattern of social and economic change.

His argument on the need to renew past efforts in harnessing science and technology for development is reinforced by his views about the current phase of rapid scientific and technological development in the advanced countries, especially in the area of biotechnology and electronics and information technology, which are regarded as the bases for the new direction of development.

Amilcar Herrera (1982) goes further in search of developing the idea of new direction of development. His work anticipates a new technological development paradigm for poor countries based on his concept of development. After presenting a critical analysis of the models adopted by many developing countries, he argues that even if it were possible for the countries that it would be undesirable as it would lead to the same situation of social and international inequality, wasteful use of resources, destruction of the natural environment, and social alienation, that beleaguers the West. The problem, Herrera argues, is how to define a new path of development that represents a rational answer to the needs and aspirations of the deprived majority of mankind. His view of the fundamental objective of development is the creation of a society in which each human being has the opportunity to fully develop his or her potentialities, [and] the first level comprises those values and elements of social organization that are the preconditions to making the basic goal possible. The first goal, then, is the reduction of inequalities for such basic needs as nutrition, housing, health and education; and the final goal should essentially be egalitarian humanity.

Herrera (1982) proposes a new approach to the generation of technologies for developing countries based on what he calls a set of assumptions. He argues that the set of assumptions held by many researchers in developing countries is similar to that held in advanced countries. All research on the traditional sector, for example, implicitly starts with the idea that the set of assumptions of criteria applied to the modern sector are equally valid for the traditional sector. In conclusion, he says the research and development system of the developing countries does not direct its research on the set of assumptions embodying a whole new concept of development. He proposes a methodology for the development of technologies not included in the set of assumptions. This methodology is adjusted to the new concept of development and would be based on the traditional technologies in use.

Such a search for new methodologies for the generation and diffusion of technologies in the Third World reflects an urgency demand to meet the basic needs of the majority of the population and a dissatisfaction both with the process of technical change, which is essentially linear from research institutions down to farmers through the extension institution.

Writing about American agriculture, Rosenberg (1976) points out that the solution to agricultural problems and the ability to make appropriate adaptations to local conditions will hinge upon the kinds of knowledge which are no ordinarily possessed by the cultivator biology, botany, biochemistry, genetics. Major breakthroughs in agriculture are likely to come from the application of the local scientific disciplines.

He further argues that a major goal of institution building in poor countries should be to equip them with research abilities and facilities that enable them to produce the knowledge required for their own peculiar agricultural work.

Agriculture's close involvement with nature has another important consequence for the acceptance of new techniques because of the importance of even minor variations in rainfall, sunshine, soil content, topography or plant diseases; there is a much higher degree of uncertainty concerning the application of new agricultural techniques. Institution building in agricultural environments will have to take the element of uncertainty into account. Institutional arrangements which serve to reduce this uncertainty or to protect the cultivator against a loss that could be personally disastrous may prove to be extremely important in spreading the adoption of new techniques.

According to Rosenberg, (1976) the history of countries with highly productive agricultural sectors indicates clearly that the major sources of improvements in agricultural productivity have been generated outside the agricultural sector. Unless an economy is well equipped with these complementary sources, agriculture is not likely to experience rapid improvements in efficiency. He further points out that in the American experience the source productivity growth in agriculture come from the machinery-producing sector, which developed a mechanical technology appropriate to agriculture; from research at agricultural experiment station and other education all institutions, from the fertilizer industry and, increasingly in the 20th century, from the study of genetics and from chemistry. In fact, in American agriculture industries which supply agriculture with certain inputs have played a key role in the introduction of new technologies entirely analogous to that of the capital goods industries in relation to the manufacturing sector.

Writing about the Japanese experience, Rosenberg states that the improvement in Japanese agricultural productivity, which provided the basis for the growth of the rest of the economy, rested firmly upon inputs provided from outside the agricultural sector. The growth of her agricultural productivity was due to a long series of dynamic interactions between the needs of the farm sector, on the one hand, and the combined ingenuity of industry and the educational establishments to supply these needs, on the other. The outcome of these interactions included the provision of low-cost commercial fertilizers, new farm implements, high quality education and extension work and at a later stage, the beginnings of mechanization.

Hayami and Ruttan (1971) stressed that a key feature of Japanese agricultural development in the early decades of this century was not so much the introduction and diffusion of new technologies themselves but rather the diffusion of the concepts and methods of improving seed varieties and cultural practices suited the local environmental conditions. Thus, after examining the experience of some developed and developing countries, Hayami and Ruttan (1976) point out that a major challenge for the developing countries is to develop the scientific and institutional capacity to design location-specific agricultural technology adapted to technological and economic environment in which the new agricultural technology is to be employed.

Ruttan and Rosenberg's views of the Japanese and American agricultural development experience do not represent a simplistic either or approach but suggest that the challenge for the developing countries in generating technical improvements in agriculture depends on the close interaction between agricultural supply firms, farmers, extension and research and development on the one hand, and developing the indigenous capacities of farmers, on the other hand. In this context, Martin Bell (1985), emphasized that none of the societies which had earlier made the transition from technological underdevelopment did so by relaying solely on the use of technology that was acquired ready-made from more advanced economies. All of them did draw very heavily on such imports. But they combined that with their own considerable efforts in adapting and improving what was imported. However, that internal technological dynamism was only rarely reflected in major technological innovations. It was much more reflected in a continuous stream of incremental technical changes.

For example, Martin Bell (1985) points out that the Japanese experience of agricultural development over the period 1880-1920 owed almost nothing to imports of ready-made agricultural technology even the increased use of fertilizers drew heavily on indigenous sources. Moreover, it owed almost nothing to major innovations based on imported methods of agricultural research and development. Over the whole period the technical changes underlying the path raising output and efficiency was to generate almost entirely by improvements, refinements and location-specific adaptations of agricultural technologies already existing in Japan combined with continuous, but largely small-scale, improvements to land drainage and irrigation. This experience is not peculiar to Japan but a range of similar development efforts have been attempted and implemented in Africa (Paul Richard, 1985).

Martin Bell further argues that the internal and largely incremental technological dynamism which played such a key role in these earlier transitions from technological backwardness obviously depended heavily on the application of relevant kinds of skills and knowledge. However, it is misleading to assume that these earlier late developing societies were already well endowed with the necessary human resources when they entered into the process of catching up with more advanced economies something it has been argued, that distinguishes them sharply from the developing countries of the 1950s and 1960s. Similarly, as with technology itself, selective and adaptive imitation of institutions was combined with a continuing succession of home-grown institutional innovations. These were developed out of the experiences of the societies themselves and they were designed to meet particular needs as they emerged at particular times.

This broad pattern of evolutionary institutional development leads one to question why the research and development systems and institutions of developing countries were created and are still being created with the same structures and on the same general principles of those in existence in the industrialised countries. It was assumed by the sovereign states, donors and others that once a modern scientific system came into existence with the same quality of personnel equipment, etc. it would become naturally connected with the production system through the classical chain of basic, applied and development research.

Clearly, those expectations were not met. For example, Charles Cooper (1973) writing on science technology and production in the underdeveloped countries states that the uncritical notion that it would be easy to orient science and technology towards productive purposes in the less-developed countries has been superseded by a more analytic (and sceptical) approach. Scientific activities in less developed countries themselves tend to be a form of consumption rather than investment and the reasons for this lie in dependence on external sources of technology and in the structure of underdevelopment itself. Yet dependence on proprietary technology from the advanced countries raises its own problems. Some of these arise because production technology is often in private ownership; it is the property of large enterprises.

Others arise because Western technology is inappropriate both because it produces over-specified commodities and because it makes intensive use of resources, which are scarce in less developed countries.

It is clear that indiscriminate transfer of technology from industrialised countries is not an adequate solution to the problems of developing countries.

In Cooper's words the little scientific and technological research that does take place within LDCs is more (or less directly or indirectly) likely directed towards the needs and interests of the international scientific community than towards the needs of the indigenous productive sectors. The scientific institutions are alienated from productive activities or marginalised because there is no demand for locally developed technologies from the productive sectors. Consequently, science in underdeveloped countries is largely a consumption item, whereas in industrialised countries it is an investment item. Furthermore, the lack of pressures on science from the local economy means that the main determinant of research orientation are the individual decisions of research workers, and these research workers take their lead from the international orientations of research. The scientific communities in the underdeveloped countries are outposts of advanced countries' science, with very limited links with the economic and social realities that surround them. There is no conspiracy or individual bad faith; it is simply the way the system works (Cooper 1977).

Skorov (1978) further seeks to explain the situation by pointing out that another specific feature of the scientific and technological revolution, which partially determines the differing intensity of its impact on industrially developed and developing countries, is connected with the fact that the basic lines of development of research and development are determined to a decisive extent throughout the world by the social need of their highly developed countries. About three-quarters of all research and development expenditures in the developed capitalist countries bear no direct relationship to the urgent needs of the Third World. Furthermore, according to Sherov (1978), a study of this question based on the experience of many developing countries and authoritative statements made by directors of international and national scientific organisations leads to the conclusion that a major and extremely widespread weakness in the present state of science in the Third World - its Achilles heel – lies in the fact that a significant number of research institutes undertake research which is irrelevant to the basic requirements of national development.

Herrera (1982) concludes that despite the advice and material help of international institutions and scientific centres of the advances countries, the research and development system of the underdeveloped countries proved incapable of generating any significant amount of indigenous technology. Even in the field of adaptation, which looked more promising in recent years, they are only able to introduce minor modifications to adapt a final product or process to local raw materials or to make better use of a particular combination of factors in the country involved. In solving the basic problems of the traditions sector of these societies, the contribution has been negligible.

As discussed earlier, the causes of the failure of the research and development systems of the developing countries to contribute to solution of the problems of the traditional sector of their societies are obviously complex. They include socio-economic, political and institutional as well as technological factors. For example, in Third World countries, the power structure forms a crucial component in development (Hyden, 1980). In the same way, this power structure and the interest groups both internally and internationally forms a necessary ingredient in discussion and analysis of research and development policy. Thus there is need for much more intellectual work in this sphere, realising that a lot can also be learned by looking at the problem in its totality.

International Transfer of Agricultural Technology and Institutions: Overview

The history of agricultural practice underscores the importance of international transfer of biological materials, plants and animals. Many of the changes in production practices of industrialised countries indicate that the international and intercontinental diffusion of cultivated plants and animals, hand tools and husbandry practices was a major source of productivity growth in pre-history and in classical civilisations, through migration, trade, expedition and colonisation. Transfers of biological technology had long been recognised as potentially the most important source of improvement in animals and plants. Before agricultural research and extension were institutionalised, this diffusion took place as a by-product of travel, exploration and communication undertaken primarily for other purposes.

Although a considerable genetic pool of plants and animals exists in Third World countries, offering opportunities to accelerate the process of transformation, the organised agricultural research institutions focus on transfer of usable hardware, plant and animal genetic materials from organised research institutions for further research work rather than focusing on their natural endowments. Such perceptions and research efforts may be seen by examining research activities and the breeding programmes being carried out and their relationship with the informal sector, where the transfer process is mainly carried out, and its relationship with the informal sector, where the transfer process is mainly carried out informally in the rural environment.

According to Ruttan (1971), the most dramatic example of agricultural technology transfer during the past several decades has been the development and diffusion of high yielding varieties of rice, wheat and maize in the tropics. This process involved more than the diffusion of high yielding varieties and the modification of husbandry practices. It involved a transfer of the capacity to invent a new location-specific biological technology. It further involved the transfer of scientific ideas, the migration of individual scientists, and the establishment of relatively sophisticated research facilities. Although in agriculture there is no uniform model of the international transfer process or classification of transfers in industry, Ruttan (1975) suggests a typology of transfer distinguishing three phases or levels of agricultural technology transfer, as follows: The first form of transfer is that of material transfer. This form of transfer is characterized by the simple transfer or importation of new materials such as seeds, plants, animals and machines, and the husbandry or management practices associated with these materials. Local adaptation through systematic selection of superior individuals or populations and the adaptation of husbandry and management practices are not highly institutionalised. The naturalisation of plants and animals tends to occur primary as a result of trial and error by farmers. The analogy in industrial technology transfer is the turnkey plant.

The second form of transfer is design transfer, which is characterised by the transfer of information in the form blueprints, formulae, journals, books and related software. During this process exotic plant materials, animal breeding stock or prototype machines may be imported for testing purposes to obtain genetic materials or in order to copy these designs.

New plants and animals are subjected to systematic testing, propagation, and selection. Imported machines are tested and designs modified to adapt them to local ecological conditions or to different tasks.

Ruttans third and more advanced stage is the capacity transfer which occurs primarily through the transfer of scientific and technical knowledge and capacity. The objective is to institutionalise local capacity for invention and innovation of continuous stream of locally adapted technology. Increasingly, plant and animal varieties are developed or prototypes developed elsewhere. As local agricultural science and engineering capacity is strengthened, both biological and mechanical technologies are invented that are precisely adapted to the ecological conditions and of the local economy.

Ruttan (1971) further points out that an important element in the process of international capacity transfer is the migration of individual scientists and the building of institutions with advanced research development and training capacity. He further argues that in spite of advances in communications, diffusion of the concepts and crafts of agricultural institutes (CIMMYT, IRRI, CIAT, ICRISAT) and much of the institution-building effort of the international aid agencies can be viewed, the need to speed up entrance of the less developed countries (LCDs) into the capacity transfer stage (Ruttan, 1971).

As noted earlier the focus on modernisation of agriculture in the Third World emphasizes transfer of technology and institutions with less attention being paid to informal and formal institutions that are problematic. Martin Bell (1985) points out that in agricultural research, farmers were seen as technologically passive adopters and users of technologies. What had to be diffused, therefore, was not technology in the form of concepts and methods for improving seed varieties and cultural practices suited to the local environment conditions but ready-made technology for specific new varieties and practices. Along with this came advice about how to use them. Creative human resources were obviously required in the research and development extension pipeline, and educational effort was concentrated on producing scientists, officials and extension agents who would staff the initiative.

The institutions, transferred and organised on a centralist, linear model (research-----> extension ------>farmer) have also suffered because agriculture is location-specific and entails a biological process.

The conventional model has thus been criticised mainly because scientists determine the research priorities, define the characteristics, and develop technologies in controlled conditions and give no attention to the problems of resource -poor farmers (Chambers and Jiggins, 1985). For example, Chambers and Jiggins (1985) powerfully argue that the prevailing methodologies of agricultural research serve the rich minority the environment and conditions under which RRFs farm are similar to those of the research station so that what works there will usually work with them. They are articulate and influential; and whether they grow food crops for the market or industrial crops they have effective lobbies and funds to influence or sponsor research. They share class and professional attitudes and values with agricultural scientists, with whom they quite readily interact. Moreover, normal agricultural science is reductionist, excelling in exploring the relationships of a restricted number of variables in controlled conditions. For environmental, economic, social and methodological reasons most agricultural science serves the needs and capacities of the rich.

The writers further argue that the prevailing model of transfer of technology in of agricultural research fits badly the needs and priorities of resource-poor farmers. This is reinforced by education and training government and commercial funding, research methodology; and professional and personal rewards and incentives. In Ethiopia, the Agricultural and Extension System of the country was catering more to the needs of the state farms and producer co-operatives than individual farmers who were the majority, thus affecting the total productivity of the agricultural sector.

Recently, recognition of the problem of the centralist, linear model of technical change and its strong bias towards resource-rich farmers has been well documented. Amilcar Herrera (1982); N. Clark, (1980); S. Biggs (1978); S. Maxwell (1984). For example, Amilcar Herrera (1982) proposed approach based on traditional technologies on the participation of peasants in the research process and the integration of the modern research and development with the experience and knowledge of the traditional societies.

CIMMYT (1980) focused on an approach termed Farming Systems Research (FSR), which is regarded as a research process, and calls for collaboration between scientists and farmers in the design of technologies. The approach is regarded as holistic and focuses on the interdependencies between the technical and human elements of farming with the aim of increasing productivity in a way that is useful and acceptable to the farm family. The FSR approach differs from the conventional top-down hierarchical approach in that it encompasses an understanding of the farming systems, and the trials are formulated and carried out under farmers conditions before being diffused to other farmers. However, this approach is criticised by Chamber and Jiggins (1985) and others on the grounds that the approach is used by scientists to set up research priorities. The packages of solutions are designed and provided by scientists to extension agents, and the distinguishing characteristics of this approach is that the knowledge of farmers is not incorporated in the design of technologies.

More recently, the Training and Visit Model (T&V) approach (Benor and Morison, 1977) has been strongly supported by the World Bank. The T & V model, like the FSR, is an extension of the conventional, linear approach. However the model encourages closer interaction between scientists, extension officers and farmers. It is designed to create a demand on the research and development. Like the FSR, the results obtained at the experimental station are verified under farmer's field conditions, for further improvement. This approach can be described as an attempt at creating a decentralized diffusion model than as an example of the centralist periphery model. Finally, there has also emerged recently the Farmers First and Last (FFL) model, proposed by Chambers and Ghildyal (1985). The main characteristics of this approach are that research agendas are determined by the farmers with research and development taking place on the farm, and with research stations and laboratories more of referral and consultancy roles. The technology generated usually entails direct satisfaction for the perceived needs of the family, low risks and low or no reliance on purchased inputs.

It is interesting to note that although these different approaches emerged in response to the concerns on the transfer of technology and institutions to rural areas in the Third World most of them are similar to the modernization process of the 1960s. Furthermore, they all attempt to prescribe models to be transferred. However, some point out the need for an evolutionary approach.

Despite this, it may not be surprising that considerable confusion continues to surround agricultural research. It should be emphasized that there are many gaps in knowledge of the conception of agricultural science and technology for development. It is not surprising to have different views and understanding of the terms and concepts commonly used in the study of technology transfer and development. For example, talk of improved production practices, agricultural innovation, technology, or technological change, while others talk of techniques or technical change. The divergent views about technology in many disciplines has resulted in misleading identification of technology with science, applied science, hardware, material artefacts, or with products of technology. There is also a misleading reference to science and technology as research and development.

Wrong use of the terminologies and concepts distorts our understanding of the concept of technical change. Technical change is generally perceived in terms of a moving production possibility curve, and in terms of the increasing number of goods and services.

However, growth in agricultural productivity takes place if technical change is introduced and adopted significantly.

The essence of technology has been well stated by Mansfield (1968): "The term technology in its broad meaning connotes the practical arts. These arts range from hunting, fishing, gathering, agriculture, animal husbandry and mining through manufacturing, construction, transportation, provision of food, power, heat, light, etc to means of communications, medicine, and military technology. In this sense technologies are bodies of skills, knowledge and procedures for making, using and doing useful things."

Thus a machine itself is not technology nor is a method of production per se. Knowledge about a machine or about a method of production is technology. It also includes the underlying knowledge, which was drawn on to produce the machine, product or method. Technology is society's pool of knowledge regarding the industrial arts. It consists of knowledge used by industry regarding the principles of physical and social phenomena (such as properties of fluids and the law of motion, knowledge regarding the application of these principle to production such as the application of genetic theory to the breeding of the plant) and knowledge regarding day-to-day operations of production (such as the rules of thumb of the craftsman). Technological change is the advance of technology, such advance often taking the form of new methods of producing existing products, new designs which enable the production of products with important new characteristics, and new techniques or organisation, marketing and management. It is important to distinguish between a technological change and a change of technique. A technique is a utilised method of production, whereas a technological change is an advance in knowledge; a change in technique is an alteration in the character of the equipment, products and organisation that are actually being used.

Martin Fransman (1984) defines technology broadly so as to encompass everything pertaining to the transforming of inputs into outputs. Thus technological change involves change, however minor, in the way in which inputs are transformed into outputs including changes in the quality of outputs.

In this sense, technologies are bodies of knowledge, skills, methods and procedures associated with the production of socially useful goods and services from the products of the natural environment. This implies that increase of productivity (technical change) occurs when farmers acquire the knowledge and skills to change the existing production techniques and not through a simple transfer of material inputs (fertilizer, improved seeds, herbicides, etc) Technology in agriculture is a process of innovation in which the output (wheat, barley, etc) remains unchanged. Change in productivity is brought about by using improved seeds. Technical change is embodied in the new improved seeds. Thus the improved seed itself is not a technology.

The Theory of Technical Change in Agriculture and Research Policy

There is relatively little information on theoretical approaches to technical change and development particularly with reference to agriculture in Third World countries (Reynolds, 1975). Perhaps the most extensive literature on technical change in agriculture is by writers concerned with issues ranging from factor endowments (Schumacher, 1973; Hayami and Ruttan, 1971), to equity and distribution (Griffin, 1974; Pears, 1980) and the integration of the Third World agriculture in the world economy (Reynolds, 1975). Technical progress was the most influential factor in the industrial revolution of industrialised countries. However, with reference to development and agriculture among small farmers, various theories of growth and models have been postulated. Again, they focus on different levels depending on the objective of the study, ranging form the state and the market, to family labour. For example the dual-economy model recognises two sectors in underdevelopment: one modern and one traditional co-existing in the national economy. This model does not imply an actively hostile environment in which, poor producers operate; it assumes that with growth and, over time, the small farmers' problems will disappear (Jorgenson, 1969).

Another model may be referred to as the efficiency model of the poor producers in traditional agriculture (Schultz, 1964; Mellor, 1967). This model does not link the small producers to the national growth of the economy assumes a socio-economic environment without conflicting interests. It assumes that, with proper incentives through the introduction of new and profitable technology, access to inputs the markets and poor producers will make their way out of misery and poverty.

This approach is further amplified by Schultz (1978) who argues for better education and necessary institutional changes. A third model may be described as the centre and periphery model (Stavenhagen 1969). This model focuses on the theory of unequal exchange of exploitation between the centre and the periphery at the level of the world economy, urban and rural areas. This means that the marginalization of the peasantry is a prerequisite to the transfer of surplus value form a less developed periphery to a developed centre. One of the characteristics of this model is that it includes social conflict and political power in the analysis, arguing that poor producers operate in an environment characterised by conflicting interests. A fourth model is based on Chayanovs theory of the peasant economy (Thorner et al, 1966). This model focuses on family labour to which any introduction of technology should be valued. This model assumes that the solution to the peasant problem is found through collectivisation of agriculture into large-scale co-operative farming. Although this model was tried in Ethiopia during the Derg regime, it failed with a disastrous consequences.

In reviewing these models and approaches, little attention has been devoted to policy issues on agricultural research that might be useful to policy-makers seeking to improve the performance of agricultural research activities. So far, the exception seems to be an attempt by Hayami and Ruttan (1971) who developed an technical innovation model. This model is developed to encompass induced institutional change (Bisnwanger and Ruttan, 1978). In it, cost reducing technologies are said to be induced by the change in relative factor prices, resulting from changes in a national relative factor proportions. The model was originally developed by using comparative historical data for the United States and Japan. It illustrated that in the USA, where labour was short, and land and capital were relatively abundant, land and capital-intensive technology was induced. These appropriate technologies had been induced because the market price of land, labour and other factors of production reflected relative national scarcities. In this model, the efficiency of the pricing system is vital for development. However, one major weakness is that it assumes perfect market mechanisms and price signals.

Another approach is suggested by N. Clark (1980) and Biggs and Clay (1981), for the understanding and analysis of rural changes, where the emphasis is placed on formal and informal institutions which are sources of technology. By focusing on institutions, it is reported that a better understanding will be achieved both of the environments in which these institutions operate and the decision-making process by scientists. This approach is further reported to allow for a closer exploration of the scope of research and technology that will benefit the poor. After analysing the relationship of the formal and informal research institutions, Biggs (1980) proposes an ideal international research and development system to benefit poor people in rural areas. The system looks like a circle. At the centre are the institutions which co-operate and interact with national programs. This national programs then exchange information and have strong linkages with rural areas, whereby they interact with local informal systems.