Agricultural Technological Research & Development in Developing Countries

By In Keun Wang*

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1. Introduction: Agriculture in National Development

The significance and importance of agricultural development in the context of the total national development of a country or of an economy may be characterized by the fact that the majority of the people in late-developing countries now depend on agriculture for their livelihood to a great extent, and that many of the resources for agricultural production are not transferable to use in other types of production in these countries. The poorer nations need a faster rate of growth to reduce the gap between themselves and the richer countries. But a faster rate of growth requires a higher rate of investment, the means for which are lacking in the developing countries in most cases. External aid can contribute to the economic resources of a country, but it is not possible to rely only on foreign aid to achieve development.

The political leaders of the developing countries observe that the advanced countries are industrialized, and therefore, they conclude that reaching a given level of development in effect is equivalent to reaching a given level of industrialization. Consequently all stress and effect have to be put on industry at

* The Author is Professor of Rural Sociology and Development, Department of Agricultural Economics, Seoul National University.

the expense of agricultural development. This seems to be reinforced by the perception that there are many obstacles to the accelerated progress of agriculture in the developing countries. Naturally there seem to be fostered notions of "the low reward accorded to agriculture" and "the prestigious place of industry."

But agricultural development as a pre-condition for industrialization should be realized. The agricultural sector forms the base of the traditional economies of the developing countries, and assigning priority to this base offers a developing country a number of potential advantages *vis-a-vis* industrialization.(1) Agricultural development can provide a tenable basis for industrial development, a fact which means that development of agricultural sector serves to hasten the process of industrialization. From the standpoint of the developing nations, the direct process (industrialization) is not the most efficient one: developing agriculture is in fact investing in industry. The interrelatedness of agricultural development and industrialization assumes that progress in agriculture is a distinct possibility. However, the proposal that first priority should be assigned to agricultural development does not imply that all efforts to initiate industrialization should cease.

Agricultural production in the developing countries is falling behind the increase in the population. Therefore, not only for humanitarian and economic reasons but for political reason, change in terms of agricultural development should be made as Cole(2) pointed out. But whenever one thinks about agricultural development, it is important to keep in mind the multiform variety of physical, economic, and cultural circumstances within which the rural people of the world live. It has been well understood that many, but by no means, all of the low-income rural regions of the world are characterized by dense population, complex social structure, and small, largely subsistence farms, each

(1) See, for example: Joseph Klatzmann, "Agriculture and Industry in Developing Countries," in Raanan Weitz, ed., *Rural Development in a Changing World*, MIT Press, 1971, pp. 113-123.

(2) John Cole, *The Poor of the Earth*, Macmillan Press, Ltd., 1976, pp. 73-88.

made up of scattered plots of land. Furthermore, agricultural development should be properly understood: it is not independent of development in other sectors of the economy. Instead, the most rapid agricultural development can only occur when substantial industrial development is taking place and when social and political developments make their essential contributions.

The urgency of economic development in the less-developed areas of the world is now generally agreed on, and rapid growth in agricultural output and productivity, namely, agricultural development, has become widely recognized as essential in effective development strategy, particularly during early stages of economic growth.(3) The process of economic development necessitates the general transformation of an essentially agricultural economy, with the great bulk of the population employed in agriculture, into an integrated economy, employing the largest share of labor force essentially in industry. The major targets in agricultural development would be two-fold: (a) within the framework of a national development plan, a larger ratio of existing national resources should be devoted to the development of agriculture; and (b) all efforts should be made to increase agricultural production, in particular, food. And we should keep in mind the fact that agricultural development does not depend on farmers and agricultural technicians alone; it is a function of the whole culture, the whole way of life.(4)

Under all circumstances, increasing agricultural productivity makes important contributions to general economic development and that, within considerable limits at least, it is one of the preconditions which must be established before a take-off into self-sustained economic growth becomes possible. As pointed in the above, agricultural development is normally a pre-requisite for industrial development, and it is also equally clear that industrial urban development

(3) Yujiro Hayami and Vernon W. Ruttan, "Agricultural Growth in Four Countries," in Yujiro Hayami, Vernon W. Ruttan and Herman M. Southworth, eds., ***Agricultural Growth in Japan, Taiwan, Korea and the Philippines***, East-West Center, 1979, pp. 3-26.

(4) Arthur T. Mosher, "Research on Rural Problems," in Robert E. Asher *et al.*, ***Development of the Emerging Countries: An Agenda for Research***, The Brookling Institution, 1962, pp. 71-119.

creates conditions much more favorable for increasing agricultural productivity and output. A little more specifically, the fundamental role of agriculture in general terms in generating development is to make labor and, in some instances, capital resources available to the industrial sector. To do so, agriculture may be able to draw on disguised unemployment and on innovations which will increase agricultural output with a minimum injection of outside capital into the agricultural sector. An increase in output per man-year can be achieved through technological progress in agriculture as made available by research and development activities, and whenever feasible, through capital accumulation within that sector. A number of policy means may be thought of appropriately at different stages of agricultural development for increase in the productivity of the existing resources in agriculture and the consequent potential freeing of resources for use in the nonagricultural sector.

The leaders of the developing countries are on the right track in their belief that industrialization is the key to economic development. The best way to reach the goal is to assign the first priority to agriculture in their development, however. The most important policy prescription which may be suggested at an early stage of development—apart from an attempt at controlling population growth—is to push the adoption of new and nontraditional technology in agriculture at a relatively small capital cost.(5) The technology to be made available appropriately through research and development activities increases productivity in agriculture, releasing labor resources. Consequently, research and development activities play a very important role which is one of the most important basic necessary conditions for a growing factor of agricultural innovation in technology and consequently of agricultural development.

II. Technological Change and Agricultural Development

The "technology factor" in either its embodied or disembodied form is in-

(5) Erik Thobecke, "The Role and Function of Agricultural Development in National Economic

creasingly recognized as a major source of differences in productivity and welfare in agricultural development over time and among countries. Yet technical change is one of the most difficult products for a country in the early stages of economic development to produce.[6] The ordinary engineering names or descriptions of technology are usually qualitative and may refer to a set of physical, chemical or biological processes. A technology may be defined by an economist by identifying and measuring the various inputs of productive resources that are used to create a certain output. In other words, technology may be the amount of inputs necessary to achieve a particular output. Technological change may be also defined directly or it can be defined indirectly in terms of its effects on the productivities of inputs. Mansfield[7] offered the following direct definition: "Technological change is the advance of technology, such advance often taking the form of new methods of producing existing products, new designs which enable production of products with important new characteristics, and new techniques of organization and management."

There is general agreement that technological change has a central role in the improvement and development of the economic conditions of the peoples of the less-developed areas. But in some cases, technological change is opposed by strong forces of tradition that attempt to forestall the consequent social changes though it is recognized that technological change is important for the less-developed areas. The role most commonly assigned to technological change is the achievement of more rapid rate of economic growth and improvement of the standard of living than would otherwise be possible. The rate at which technological change can be implemented is not independent of other economic conditions, to be sure, and there is a great scope for all the tools of economic policy. In addition, technological change is regarded as one of the

Growth," in *Economic Development of Agriculture*, Iowa State University Press, 1965, pp. 269-285.

(6) Gould P. Colman and Jerry D. Stockdale with Thomas W. Scott and Theodore W. Bateman, *Area Development through Agricultural Innovation: New York's Sugar Beet Fiasco*, West Virginia University, 1977, p. 47.

(7) E. Mansfield, *The Economics of Technological Change*, Norton, 1968, pp. 1011.

major instruments for necessary changes in the general social structure reflected by economic and technical patterns. In principle, the problems of technological change in advanced countries are not different from those in underdeveloped areas, but practically, they are of a different magnitude. The technological changes have become imbued with cultural traditions so that a change in production methods requires fundamental adjustments in all aspects of the society. And technological change in underdeveloped areas is nearly always imported from advanced countries. While some of technological imports may economize on all factors and be physically more efficient than existing technologies, other imported technologies may very well economize on the wrong factors.

Agricultural development is a ubiquitous human activity, occurring widely in both time and space. Every agricultural development plan will contain assumptions about (a) human behavior, (b) environmental conditions, and (c) available technology. Our concern here is technology, and the rate of technological change depends upon the extent to which economic and other social conditions generate a readinss to adopt new technology. Schultz[(8)] has suggested that significant growth in productivity cannot be brought about by the reallocation of resources in traditional agricultural systems. Significant opportunities for growth will become available only through changes in technology—new husbandry techniques, better seed varieties, more efficient sources of power, and cheaper plant nutrients.

Agricultural technology can be generally seen as the application of knowledge to agricultural tasks which is commonly divided into three types: (a) biological technology, (b) chemical technology and (c) mechanical technology.[(9)] But McInerney[(10)] insisted that "technology" is more than just resources, or knowledge, or methods of production; it embraces the whole system of technical, economic, institutional, social and political arrangements that characterize the

(8) Theodore W. Schultz, *Transforming Traditional Agriculture*, Yale University Press, 1964.
(9) Yujiro Hayami and Vernon W. Ruttan, *Agricultural Development: An International Perspective*, Johns Hopkins University Press, 1971, p. 2.
(10) John P. McInerney, *The Technology of Rural Development*, World Bank, 1978.

way a society functions. Therefore, aside from the "direct" or intended agricultural output, input, and income effects, the changes initiated also create consequent "indirect" effects such as (a) pressure on the physical and institutional infrastructure of the region, (b) developments in the linkages with nonagricultural activities and in the commercial character of farming, (c) shifts in the distribution of income, consumption, wealth and ultimately influence among different groups in society, and (d) often major changes in the values, attitudes, expectations, customs and behavior patterns of rural society. Development can be viewed as technological change and technology as the whole system of technical and nontechnical parameters within which a society functions. Consequently, it may be advanced that a much more "holistic" approach is necessary for technological change and agricultural development in which economic, social, and institutional adjustments are an integral part.[5]

According to Pihkala, the word "technical change" tends to give an impression of something concerned with machines. The word, however, may be used in its present context in a broader sense to include all kinds of innovations produced by the mental ability of mankind and aimed at contributing to increased efficiency of production. Thus, changes effected by breeding and improvements in cultivation and in the feeding of farm animals are included, as well as the invention of new machines and implements. On the other hand, changes in the social structure, land tenure, etc., in spite of their effects on agricultural efficiency, are generally not included. It is clear that interdependency exists between technical development and social forms, but when analyzing technical change, it is always desirable to isolate its effects from those of social change.[11] As a matter of fact, a United Nations agency in Asia analyzed agricultural technical change in terms of four categories: (a) the high-yielding varieties

(11) K.U. Pihkala, "The Meaning of Technical Change in the Context of the Agricultural Economy of Different Environments: (a) Scandinavia," *Proceedings of the Ninth International Conference of Agricultural Economists*, Oxford University Press, 1956, pp. 17-31.

(HYV), (b) chemical fertilizer, (c) irrigation facilities or water management, and (d) mechanization.[12]

Rapid growth in agricultural output and productivity has become widely recognized as essential in effecting agricultural development strategy, particularly during early stages of economic growth. Here rapid growth in agricultural output and productivity comes as a result of agricultural technological change. In recent years, the demand for agricultural output has in many countries increased by 4 to 6 percent a year. Achievement of output growth rates commensurate with the increasing demand depends upon making available high-payoff inputs embodying new technology that increases the productivity of land and labor.[13] From another viewpoint, technological changes in agriculture have impacts upon both farming and farm people. The former results in starting realizing food increases in output per acre, per animal and in total farm output. In the latter, viewed in historical perspective, farm people as a group have benefitted greatly from the technological changes and improvements.[14] It is a well-known fact that technological factors in the development of Japanese agriculture have been significant. The capital investment associated with these technical improvements and changes was modest and mainly took the form of requirements for working capital that gave a quick payoff in increased output, and, moreover, these technological innovations were adapted to the existing framework of small farm units.[15]

Perhaps the most dramatic example of agricultural technology which achieved new embodiment of existing scientific knowledge in a uniquely appropriate form in underdeveloped countries to be found in the domain of agriculture should be the case of developing technology on high-yielding varieties of cereal crops, especially wheat and rice, usually dubbed as "genetic engineering in

(12) United Nations, *Economic and Social Survey of Asia and the Pacific 1975*, 1976, pp. 61-95.
(13) Yujiro Hayami and Vernon W. Ruttan, "Agricultural Growth in Four Countries," in Hayami, Ruttan and Southworth, eds., *op. cit.*, pp. 3-26.
(14) Pihkala, *loc. cit.*
(15) Food and Agriculture Organization, United Nations, *Agricultural Development in Modern Japan: The Significance of the Japanese Experience*, 1966, pp. 11-12.

rice and wheat." The technology raised the productivity of land, as well as that of labor and capital. Drawing on the same body of biological knowledge that had been utilized in developing high-yielding varieties for the temperate climates of Europe, Japan and the United States in the first half of the twentieth century, agricultural scientists in Mexico, Taiwan, the Philippines and Korea have recently bred new fertilizer-responsive plant types that are well adapted to tropical and subtropical and even temperate environments. The landmark names are "green revolution."

Canterbery and Bickel(16) even observed that the dramatic green revolution in rice, wheat, and corn shifts economic development problems from concern with widespread starvation to concern with a potential grain glut on world markets, adding that this foreshadows possibly some new trading difficulties for developed agricultural exporters and some entirely different kinds of problems for developing countries' grain consumers and producers. The history of the development of the new seeds and the precise nature of the new technology has been widely discussed elsewhere.(17) The modern technology associated with the high-yielding varieties or modern varieties (MV) is often called "seed-fertilizer" technology. Farmers' preference for MV because of their high yield suggested that the level of adoption could be related to the income advantage achieved from improved yield of the MV over the LV (local varieties) which evidences were confimed in 9 of the 14 locations in Asian countries.(18) Thus, the new agricultural technology contributed not only for increased yield but also for income and economic advantage. Kim(19) concluded emphatically (a) self-sufficiency in rice, (b) increased farm income, and (c) strengthening national power and enhancing

(16) E. Ray Canterbery and Hans Bickel, "The Green Revolution and the World Rice Market, 1967—1975," *American Journal of Agricultural Economics*, Vol. 53 (May 1971), pp. 285-294.
(17) See, for example: Lester R. Brown, *Seeds of Change: The Green Revolution and Development in the 1970's*, Praeger Publishers, 1970.
(18) Teresa Anden-Lecsina and Randolph Barker, "The Adoption of Modern Varieties," in The International Rice Research Institute, *Changes in Rice Farming in Selected Areas of Asia*, 1978, pp. 13-33.
(19) In Hwan Kim, *The Green Revolution in Korea: Development and Dissemination of New Rice Varieties*, Association for Potash Research, Korea, 1978, pp. 143-153.

national prestige as some conspicuous results of the green revolution in Korea which were primarily brought about by the introduction of new technology of high-yielding rice varieties.

Evenson,[20] however, concluded in an empirical study that the high-yielding varieties did contribute very significantly to increased production, but they were by no means the sole source of productivity gains in agriculture of developing countries. Effects of the technological change in terms of green revolution have been to raise levels of grain production very markedly. But ever since the emergence of new cereal technology in Asia, the impact of technological change on income distribution has become a major concern. Attention has focused on a number of issues suggesting that technological advance may contribute to an increased concentration of income.[21] Scobie and Posada,[22] for example, found that the rapid and widespread adoption of modern rice varieties led to substantial increase in production, but that the net benefits, both absolute and relative, accrued disproportionately to the poorest farm households. Rao[23] also concluded from the field studies in Asian countries that while the new technology has brought about a significant increase in the output of foodgrains it has not yet succeeded in giving it self-sufficiency even on the basis of current and admittedly inadequate levels of consumption and that where the new technology has been applied in substantial measure and has made an impact on agricultural

(20) Robert E. Evenson, "The 'Green Revolution' in Recent Development Experience," *American Journal of Agricultural Economics*, Vol. 56 (May 1974), pp. 387-394.

(21) The arguments cited usually include faster rates of adoption by "large" compared with "small" farmers or by owners compared with tenants, a labor-saving bias in the technology that reduces labor's share, non-adaptibility of technological innovations to all geographical areas, a tendency for public services to be available to large farmers but not to small, and incentives for wealthy farmers to consolidate small holdings into larger units, thereby promoting a polarization of the rural population (Yujiro Hayami and Robert E. Herdt, "Market Price Effects of Technological Change on Income Distribution in Semisubsistence Agriculture," *American Journal of Agricultural Economics*, Vol. 59 No. 2 (May 1977), pp. 245-256).

(22) Grant M. Scobie and Rafael T. Posada, "The Impact of Technical Change on Income Distribution: The Case of Rice in Colombia," *American Journal of Agricultural Economics*, Vol. 60 (Feb. 1978), pp 85-92.

(23) V.K.R.V. Rao, *Growth with Justice in Asian Agriculture: An Exercise in Policy Formulation*, United Nations Research Institute for Social Development, 1974, p. 1.

production, the resulting benefits by way of increased returns have not been equally shared by the different-size-groups farms with the result that the rich have grown richer and the poor therefore comparatively poorer.

A strategy of agricultural development that is oriented toward making more agricultural production, creating more productive employment, and achieving a more equal income distribution must be concerned with the range of technological choice available in the production of goods and services demanded domestically and abroad. Whereas the range of technological choice is quite limited in many sectors, there are other factors in which a relatively wide range of technological alternatives exists. In this context, agriculture provides perhaps the greatest scope for substitution between the major factors or inputs of production: labor, capital, land and intermediate inputs over a very broad spectrum. Analysis of alternative technology possibilities may be presented at the individual operation and total operations levels. For example, Bartsch,[24] with reference to those employment effects of individual operations, analyzed 7 technology items. New technology facilitates the substantively abundant (hence cheap) factors for relatively scarce (hence expensive) factors in agriculture. Chemical and biological technology is land-saving, and mechanical technology is labor-saving, for example.

III. Agricultural Research & Development and Social Returns

A constant flow of new, field-tested technological knowledge relevant to smallholder production is a pre-condition for the continuing success of technological change leading to agricultural development in developing countries. Many people of the developing countries live in a harsh environment where investments would produce little extra income until technological discoveries create reliable new opportunities for agricultural development. Inappropriate research and development programs and the inadequacies of adaptive research

(24) William H. Bartsch, *Employment and Technology Choice in Asian Agriculture*, Praeger Publishers, 1977, pp. 11-15.

have in many cases been major factors limiting the benefits reaching farmers. With small and poor farmers in mind, the World Bank[25] pointed out four essentials for technology policy: (a) the failure to treat the subsistence farm as a system of cultivation, requiring a comprehensive approach to on-farm technological improvement; (b) the lack of attention to technological factors that are especially important to the small farmer; (c) better advice on simple improvements in crop husbandry and soil and fertility conservation; and (d) development of small farm equipment. A basis for achieving rapid expansion in agricultural productivity is to generate an ecologically adapted and economically viable agricultural technology in each country. In other words, an unending stream of new agricultural technolgical knowledge and a flow of industrial inputs in which new knowledge is embodied represent a necessary condition for agricultural development. Therefore, creation of new agricultural technology, that is, research and development (R & D), is crucially important for agricultural development.

Three sequential stages in innovation process were identified by Jewkes, Sawers and Stillerman:[26] (a) "science," which is directed toward understanding, (b) "invention," and (c) "development," which form "technology," being directed toward use. The distinction between invention and development may be one of degree. Development is a combination of the three phenomena: (a) appplication of known technical methods to a new problem, (b) the search for more specific task performance susceptible to measurement, and (c) commercial considerations examined. From still another view-point, "development" encompasses (a) activities concerned with scaling up laboratory models into commercial-sized plants, (b) the search for new and better materials, and (c) the search for new machines capable of operating under greater temperature, pressures and tolerances, and of processing new shapes. Ames[27] identified four

(25) World Bank, ***Rural Development*** (Sector Policy Paper), 1975, p. 32.
(26) J. Jewkes, D. Sawers and R. Stillerman, *The Sources of Invention*, Norton, 1969, pp. 26–29.
(27) E. Ames, "Research, Invention, Development and Innovation," *American Economic Review*, Vol. 59 (June 1969).

sequential activities with the output of each stage fading into the next, borrowing from Machlup's ideas:[28] (a) basic research, (b) inventive work, (c) development work, and (d) innovation. Consequently, the Ames/Machlup framework is clearly in reasonable conformity with the categories of activities defined by Jewkes, Sawers and Stillerman in that science is basic research and both use the term "invention" to describe the second stage and "development" to define the third stage. The United States' National Science Foundation (NSF)[29] uses a similar framework of activities to define research and development: (a) basic research, (b) applied research, and (c) development. Arrow[30] has more recently gone to an opposite extreme in classifying these activities, ranging from the production of pure knowledge to the production of pure product. According to him, "inventive activity" is the same as science which is consisted of basic research and invention, and "innovative activity" is development. Furthermore, he thinks that research and development as sources of technological change interchangeably refers to the activities leading up to the production of the knowledge necessary to construct the first commercial facilities designed to produce a new product, and to inputs consumed in the production of this knowledge. Binswanger and Ruttan[31] pointed out that the process of development involves the movement of three distinct "innovation frontiers" or levels of technological achievement: (a) "scientific frontier," (b) "technology frontier" or "metaproduction function," and (c) "achievement distribution," and essentially, (a) and (b) would be equivalent to research and development.

Research and development as sources of technological change for agricultural

(28) Fritz Machlup, "The Supply of Inventors and Inventions," in R.R. Nelson, ed., *The Rate and Direction of Inventive Activity: Economic and Social Factors*, Princeton University Press, 1962, pp. 369-370.

(29) K. Sanow, "Development of Statistics Relating to Research and Development Activities in Private Industry," in National Science Foundation, *Of Statistics on Research and Development*, 1959, p. 124.

(30) K.J. Arrow, "Classificatory Notes on the Production and Transmission of Technological Knowledge," *American Economic Review*, Vol. 59 (May, 1969).

(31) Hans P. Binswanger and Vernon W. Ruttan, "Introduction," in Hans P. Binswanger and Vernon W. Ruttan, *Induced Innovation: Technology, Institution and Development*, Johns Hopkins University Press, 1978, pp. 1-9.

development are for improved and new technologies and inputs, or innovations. Generally, these activities, consequently, may be hardly considered and analyzed as separated from crucially related ones: (a) extension activities, that is, technology transfer, diffusion of technology, technology transmission, or choice of technology, and (b) teaching, education, or schooling. Research and development create new knowledge and practices, and schooling and extension distribute the available knowledge and practices, each in its own way. The complementarity between these activities is self-explanatory. Welch,(32) for example, suggested that research and development, by producing new technologies, create disequilibrium in the sense that producers find themselves in nonoptional allocation positions. Schooling produces the ability to comprehend and judge new situations and to move rapidly to take advantage of opportunities and to close allocation gaps. And extension can substitute for schooling in these respects. These theoretical considerations have been estimate-wise supported.(33) It would not be seldom, therefore, that many tried to treat agricultural research and development combined with extension and education. Here, we are concerned with research and development in agriculture, however. As already briefly described, there may be apparently two broad lines of reasoning on the contents or scope of research and development for agricultural development, that is, sources of technological change: (a) a relatively narrower but more realistic technical definition, centering primarily on biological, chemical, mechanical and water technology, and (b) a rather broader "holistic" approach, encompassing the whole aspects or factors concerned with agricultural research and development or agricultural technological change. It has been generally observed and

(32) Finis Welch, "Education in Production," *Journal of Political Economy*, Vol. 78 (January 1970) pp. 35-59.

(33) Robert E. Evenson, "Economic Aspects of the Organization of Agricultural Research," in Walter L. Fishel, ed., *Resource Allocation in Agricultural Research*, University of Minnesota Press, 1971; W. Huffman, "The Contribution of Education and Extension to Differential Rates of Change," Ph.D. Dissertation, University of Chicago, 1972; N. Khaldi, "The Productive Value of Education in the US Agriculture 1964," Ph.D. Dissertation, Southern Methodist University, 1973.

found that the former has been primarily analyzed in terms of agricultural research and development. Naturally, research and development for agricultural new technology or innovations for agricultural development is largely confined itself to this category of activities. In this connection, however, this does not imply that the latter category of research and development activities are unimportant and not conducted. On the contrary, social science aspects of agricultural technological change and agricultural development are never neglected.[34] Furthermore, it should be true that research and development for "rural development", not for "agricultural development," would be much broader and complex in that, as Kühnen[35] pertinently pointed out, agricultural development is one aspect of rural development which, in turn, is part of the overall socio-economic development.

New information, new knowledge, new technology or innovations, produced from research and development is typically endowed with the attributes of the "public good" in the Samuelson-Musgrave definition.[36] It is characterized by (a) nonrivalness or jointness in supply and utilization, and (b) nonexcludability or external economies. The first attribute implies that the good can be equally available to all and the latter implies that it is impossible for producers to appropriate, through pricing in market, the full social benefits arising directly from the production (and consumption) of the good. A unique aspect of agri-

(34) See, for example: Bryant E. Kearl, *What Should Be the Role of the Social Sciences in a College of Agriculture?*, ADC Paper, The Agricultural Development Council, Inc., May 1966; Donald C. Taylor, *Research on Agricultural Development in Selected Middle Eastern Countries*, The Agricultural Development Council, Inc., 1968 ("Research Classification Scheme"); R.J. Hildreth, "Issues and Implications in Current Procedures of Establishing Research Priorities," *Journal of Farm Economics*, Vol. 48 (December 1966), pp. 1641-1650; John T. Scott, Jr., "Reorganizing Social Science Research in Agriculture," *American Journal of Agricultural Economics*, Vol. 53 (May 1971), pp. 342-345; Clifton R. Wharton, Jr., "The Issues and a Research Agenda," in Clifton R. Wharton, ed., *Subsistence Agriculture and Economic Development*, Aldine Publishing Co., 1969, pp. 455-467.

(35) Frithjof Kühnen, "The Concept of Integrated Rural Development," *Korean Journal of Agricultural Economics*, Vol. 19 (November 1977), pp. 137-147.

(36) P.A. Samuelson, "The Pure Theory of Public Expenditure," *Review of Economics and Statistics*, Vol. 36, pp. 387-389; R.A. Musgrave, *The Theory of Public Finance*, McGraw-Hill, 1959.

cultural research and development, particularly in biological technology, is that the products at the applied end are characterized by nonexcludability. Therefore, the optimum supply of biological-research products cannot be expected without the participation of public agencies. Viewed from other non-economists' view-points, the attributes of the products of research and development in terms of "innovations" may be characterized into five: (a) relative advantage, the degree to which an innovation is perceived as being better than the idea it supersedes; (b) compatibility, the degree to which an innovation is perceived as consistent with the existing values, past experiences and needs of the receivers, (c) complexity, the degree to which an innovation is perceived as relatively difficult to understand and use; (b) trialability, the degree to which an innovation may be experimented with on a limited basis; and (e) observability, the degree which the results of an innovation are visible to others.[(37)] And it should be very meaningful and insightful that Shand,[(38)] surveying almost all countries of Asia, categorized four relationship patterns between technology and land: (a) "unlimited land-static technolgy," (b) "limited land-static technology," (c) "unlimited land-dynamic technology," and (d) "limited land-dynamic technology."

The contribution to and social returns from agricultural research and development activities have been empirically amply analyzed and established positively. Historically speaking, it was Griliches[(39)] who conducted the pioneering work in estimating the contribution of research to agricultural productivity by studying the economics of the hybrid corn innovation in the United States. He showed that both the geographical distribution of research efforts and rates of adoption of the new varieties were affected by economic considerations. The need for assessment of the contribution or productivity of agricultural research

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(37) Everett M. Rogers with F. Floyd Shoemaker, ***Communication of Innovations: A Cross-Cultural Approach***, The Free Press, 1971, pp. 134-157.

(38) R.T. Shand, "Perspective on Asia," in R.T. Shand, ed., ***Agricultural Development in Asia***, Australian National University Press, 1969, pp. 313-325.

(39) Zvi Griliches, "Research Costs and Social Returns: Hybrid Corn and Related Innovations," ***Journal of Political Economy***, Vol. 66, pp. 419-431.

and development lies in the fact that the efficient allocation of resources to and among research and development activities has become an important problem in public finance in that most research and development activities in agriculture is publicly supported in any country. In this connection, it is quite true that there is inherent a high degree of uncertainty about the productivity of research and development by its very nature. Peterson,[(40)] for example, demonstrated that past investment in poultry research in the United States has been yielding a return of about 20 to 30 percent per year from the end of the date of investment, which has also an important bearing on the general economic growth, contributing 3 or 4 percent. In the United States, an important source of new knowledge has been the United States Department of Agriculture (USDA) and the land-grant colleges which are supported by public investment, especially since 1910. Private industry, however, also makes an impressive contribution to research and development in agriculture.

Covering sixty-four wheat-growing and forty-nine maize-growing countries during the 1948~68 period (the Green Revolution had little impact during this period), Evenson and Kislev[(41)] conducted an international analysis of research and development and productivity in wheat and maize, on the basis of estimates of three components: (a) direct contribution of indigeneous reseach to productivity;(b) the accelerating effect of own work on borrowing; and (c) the contribution of research in one country to productivity in others. Furthermore, they conducted an aggregate analysis of productivity in thirty-six countries where framework for the analysis is a production function framework. The wheat and maize study in the former case incorporated only the land input but the aggregate analysis enables incorporation of more complete input data at the cost of reduced sophistication in using research information. In both cases, the data supported that investment in technological discovery activity is required

(40) Willis L. Peterson, "Return to Poultry Research in the United States," *Journal of Farm Economics*, Vol. 49 (Aug. 1967), pp. 656-669.

(41) Robert E. Evenson and Yoav Kislev, *Agricultural Research and Productivity*, Yale University Press, 1975, pp. 58-77, 78-87.

for the realization of significant increases in agricultural productivity. The estimated marginal contributions of research and development investment have consistently shown returns to investment in order of magnitude higher than returns realized on more conventional investments designed to produce economic growth. In other words, a strong functional relationship between research and development and agricultural productivity is indicated by the findings. The investment in research to improve rice technology may be estimated by drawing on a recent survey by Boyce and Evenson.[42] To determine the social returns to rice research with special reference to tropical Asia (in this case, Green Revolution had impact), Evenson and Flores[43] conducted a study whose computed returns show that investment in rice research has yielded high rate of returns. Even the conservative low estimates for the MV are extraordinarily high compared with returns on alternative investments. And it was also found that while the rates of return on investment in international research and development (IRRI) are higher than those realized on national research program investment, the returns to the latter research are also high.

Given the "public good" attributes of agricultural research and development products as described before, a socially optimum level of investment in agricultural research and development can hardly be expected if it is left to private firms. Public support is required in order to correct the failure of the market mechanism to allocate resources to agricultural research and development activities. Akino and Hayami,[44] from their analysis of efficiency and equity problems concerned with public resource allocation to agricultural research and development, using as a case the experience of the rice breeding program in Japan in the course of her modern economic growth, conclusively implied that there

(42) J. Boyce and Robert E. Evenson, *Agricultural Research and Extension Systems*, Department of Agricultural Economics, University of the Philippines at Los Banos, 1975.

(43) R.E. Evenson and P.M. Flores, "Social Returns to Rice Research," in International Rice Research Institute, *Economic Consequences of the New Rice Technology*, 1978, pp. 241-265.

(44) Masakatsu Akino and Yujiro Hayami, "Efficiency and Equity in Public Research: Rice Breeding in Japan's Economic Development," *American Journal of Agricultural Economics*, Vol. 57 (Feb. 1975), pp. 1-10.

is the evidence that an underinvestment in research and development is typical. If underinvestment in agricultural research and development was the case for Japan, as well as for the United States[45] and others, both characterized by the relatively well-established agricultural experiment station, the potential benefit from research and development for developing countries where the public research system is in an early stage should be extremely large. This inference would be consistent with the findings of very high social returns from the cotton research in Brazil and the wheat research in Mexico. Accordingly, public planners and policy makers should be constantly reminded of the tendency to underestimate the social productivity of research and development in agriculture. It may be quite generally understandable that public funds for agricultural research and development as well as for economic development are scarce in developing countries.

It is also true that competent scientists and technicians who can carry out significant research and development programs are equally scaree. Among the resources, human capital in the form of competent research workers represents the critical limiting factor.[46] The capacity of agricultural research and development at a given time point is conditioned by the historical accumulation or agricultural scientists and technicians. The form of the production function in agricultural research and development is conditioned by the fact that it includes as a critical factor scientific research personnel. Furthermore, a hypothesis has been established that agricultural research and development is characterized by scale economies: to some extent, physical buildings and equipment for research and development can be utilized more efficiently for large-size operations.[47]

(45) Griliches, *op. cit.*

(46) This point has been emphasized by many. See, for example: Theodore W. Schultz, "The Allocation of Resources to Research" in Walter L. Fishel, ed., *Resource Allocation in Agricultural Research*, University of Minnesota Press, 1971, pp. 90-120.

(47) Schultz, *op. cit.* pp. 150-152; Robert E. Evenson, "Economic Aspects of Organization of Agricultural Research"; Myles G. Boylan, "The Sources of Technological Innovations," in Bela Gold, ed., ***Research, Technological Change and Economic Analysis***, D.C. Heath and Company, 1977, pp. 103-129.

But more importantly, the productivity of agricultural scientists and technicians increases through interactions with other scientists and technicians under favorable "social climate," which may not be the case with many developing countries. Another important attribute of the research production function is its stochastic form. That is, the research and development is, by nature, characterized by risk and uncertainty.(48) Consequently, the issue of how a society or country allocates resources to the new technology input sector and how the returns are allocated among different activities within the sector is fundamental to the research and development in the agricultural development process. In other words, how to economize the scarce resources for research and development is an especially serious problem for the design of research and development organizations in developing countries.

The role of government, naturally, has been significantly great in all countries for research and development activities in agriculture.(49) Needless to mention, it would be true that where commercial agriculture, usually with relatively large operations, are practised, the contribution of private sector to the agricultural research and development activities would be relatively active, primarily being directed toward developing mechanical technology. In addition, the role of foreign assistance or international developmental assistance should be taken into consideration when discussing the present status and prospects of research and development in agriculture and agricultural development as a whole for a particular country or society. Perhaps, the most dramatic contribution to the agricultural development of developing countries has been the high-yielding varieties of rice and wheat from the work of the United States foundations. The United States Agency for International Development (USAID), a government arm for

(48) R.R. Nelson, "The Simple Economics of Basic Scientific Research," *Journal of Political Economy*, Vol. 67 (June 1959), pp. 297-306.

(49) For example, Heady declared that aside from the ownership of productive units in farming, no other nation has had a more direct and effective participation of the public sector in technical development and progress of agriculture than the United States (Earl O. Heady, "Public Purpose in Agricultural Research and Education," in Carl Eicher and Lawrence Witt, eds., *Agriculture in Economic Development*, McGraw-Hill, 1964, pp. 386-398).

foreign technical and economic assistance, has been contributing very much[50] though other countries, notably, Canada, the Scandinavian countries, the United Kingdom, France, and West Germany direct and finance agricultural development operations in a number of developing countries whose economic base is predominantly agricultural. The Food and Agriculture Organization (FAO) of the United Nations has been representing the international development assistance communities, which, in recent years, has been in collaboration with the United Nations Development Programme (UNDP). Religious and charity organizations are also active participants in the agricultural development of developing countries. The principal foreign contributions to agricultural development in developing countries may be grouped into three categories: (a) a supply of technical inputs, (b) technical advice on research, extension, and training, and (c) infrastructure installation.[51] However, because of the very nature of agricultural research and development, it appears that not so much priority attention has been given to this aspect of agricultural development process in many newly-developing countries in terms of international or foreign agricultural development assistance program. Institution-building efforts for research and development of agriculture have been tried. Korea's agricultural research and development system under the Office of Rural Development (ORD) and the Seoul National University College of Agriculture(SNUCA) could be cited as highly successful examples in this regard at the inception stage of her development. Hewes[52] estimated that developing countries finance about 85 percent of their agricultural

(50) Ruttan identified three patterns or models of US technical assistance programs;(a) "Contract Model", (b) "University Contract Model", and (c) "Institute Model" (Vernon W. Ruttan, "Research Institutions: Questions of Organization," in Melvin G. Blase, ed., ***Institution in Agricultural Development,*** Iowa State University Press, 1971, pp. 129-138.

(51) See, for example: Wayne Schutzer and Dale Weigel, "The Contribution of Foreign Assistance to Agricultural Development," ***American Journal of Agricultural Economics,*** Vol. 51 (Nov. 1969), pp. 788-797; Laurence Hewes, *op. cit.*, pp. 94-112; Gunnar Myrdal, "The United Nations, Agriculture, and World Economic Revolution," ***Journal of Farm Economics,*** Vol. 47 (Nov. 1965), pp. 889-899; James Gilbert Evans, Sr., "Foreign Aid for Agricultural Development: Philosophy and Implementation," ***American Journal of Agricultural Economics,*** Vol. 51 (Dec. 1969), pp. 1402-1412.

(52) Hewes, *op. cit.*, p. 95.

development out of their own resources. The remaining resources for development are from foreign assistance. But this small contribution plays an important role in promoting agricultural development including, of course, research and development, for agricultural technology.

IV. Technology Transfer and Developing Appropriate Technology

Country-wide research and development activities in agriculture may be considered as consisting of two major categories: (a) indigenous research and development activities, and (b) adaptive research and development activities. For the most part, the latter is based on the so-called "international technology transfer," though location-specific adaptive research and development work is planned and implemented in a country without reference to international transfer. It should be very meaningful to note that an *ad hoc* committee of the United Nations has declared several premises with respect to the application of science and technology to development, the two of which are: "the process of world development consists partly in bringing about a wider sharing of its benefits not only through trade and aid but also through the transfer of modern technology to developing countries, and obstacles hinder this technology transfer," and "there are also serious obstacles within developing countries, including an insufficient supply of trained manpower, lack of the institutions and of the resources that would be needed to train their own scientists and technicians on the scale required..."(54) As implied before, agricultural research and development activities, hence, agricultural development, in most developing countries, have been accelerated by means of the process of international technology trans-

(53) As to the basic concept of "international technology transfer", see, for example, the following: Hayami and Ruttan, *op. cit.*, pp. 169-237; United Nations, *World Plan of Action for the Application of Science and Technology for Development*, 1971; Binswanger and Ruttan, *op. cit.*, pp. 164-211. Hayami and Ruttan illustrated classical examples of international technology transfer; (a) transfer of biological technology: the case of sugar cane, and (b) transfer of mechanical technology: the tractor in Russia and Japan.

(54) United Nations, *ibid.*, p. 45.

fer, generally from developed countries, while developing countries severely lack in most cases the necessary resources for effective agricultural research and development. Not only do the less-developed countries face more difficulties in adopting changes in technology than do the economically more advanced countries, they have much more difficulty in generating new technologies suited to their conditions. The overwhelming part of the research and development which is currently going on to develop new technologies is in developed countries and directed toward their conditions. The research and development manpower and facilities in the developing countries are themselves quite limited which come from the relative poverty and slow growth rates in these countries. Therefore, developing and implementing appropriate technological changes include some of the most difficult problems in agricultural and economic development. Basically, for desirable technological change to be implemented in any developing country, there may be two major needs: (a) the present state of knowledge about technology, and (b) research and development needs and methods for finding out suitable technologies.

The adaptive research and development work, generally based on international technology transfer, has a much more significant meaning for agricultural research and development than the indigenous research and development in any developing country. And generally speaking, international technology transfer in agriculture has been the very core of any international or foreign agricultural (technical) development assistance programs for developing countries. Needless to point out, international transfer of technology is never confined to agricultural development. International technology transfer in industry, for example, has been given a great deal of attention these days.[55] Fundamentally speaking, "immanent change" may be generally commensurate with indigenous research and development (and transfer) and "contact change" may be generally commensurate with adaptive research and development (and transfer). Today, contact

(55) United Nations Industrial Development Organization(UNIDO), located in Vienna, Austria, has been doing much efforts in this regard.

change is increasingly "selective" and "directed."(56) The products of adaptive research and development activities may be generally considered "appropriate technology."(57) Consequently, a significant role of agricultural research and development activities in most developing countries rests upon the adaptive research and development activities which are based on international technology transfer in order to produce a series of location-specific appropriate technology. There is also national, domestic or local technology transfer, which is being transformed into a national government policy program of agricultural extension work.(58) The ultimate and basic role of agricultural research and development in any developing country, therefore, is to produce new technology or innovations for national, or local technology transfer through the channel of agricultural extension system. Here we see that agricultural research and development activities have a mutually very significant relationship with extension activities, that is, implementation of national technology transfer.

Efforts to achieve agricultural development by the direct transfer of foreign technology have been largely unsuccessful.(59) Modern agricultural technology

(56) Rogers with Shoemaker, *op. cit.*, pp. 8–9.

(57) In the process of extending developmental assistance to least-developed countries, the concept of appropriate technology today might be considered much less innovative, but too much resource endowment-specific. For detailed information on appropriate technology, see, for example: Nicolas Jéquier, ed., ***Appropriate Technology: Problems and Promises***, Development Centre of the Organization for Economic Co-operation and Development, 1976; German Foundation for Developing Countries, ***Development and Dissemination of Appropriate Technologies in Rural Areas***, 1972.

(58) See, for example: H.C. Sanders, ed., ***The Cooperative Extension Service***, Prentice-Hall, 1966; Lincoln David Kelsey and Cannon Chiles Hearne, ***Cooperative Extension Work***, Comstock Publishing Associates, 1963; Sara Molho and Marcia Gitlin, eds., ***Agricultural Extension: A Sociological Appraisal***, Keter Publishing House, 1970; Chi-Wen Chang, ***Rural Asia Marches Forward: Focus on Agricultural and Rural Development***, UPCA Textbook Board, 1969.

(59) Ohkawa pointed out classically that direct and full-scale importation and transfer in the early transitional years of Meiji era of Japan from Western developed countries of farm machineries, implements and crop varieties proved unsuccessful for agricultural development (Kazusi Ohkawa, ***Keizai Hatten to Nihon no Keiken*** (Economic Development and Japanese Experiences), Taimei Do, Japan). And Evenson and Binswanger illustrated three problems of direct transfer of technology; (a) the cost of activities such as information-obtaining, screening technology, and manpower training, (b) the environmental sensitivity of a technology in terms of both economic and non-economic factors, and (c) the frequent absence of research and development capacity at the applied level (Evenson and Binswanger, *op. cit.*, pp. 202–203).

has evolved largely in the developed countries and is primarily adapted to their ecology and factor endowments in the form of appropriate technology. It would be very much meaningful to distinguish the three phases of international agricultural technology transfer: (a) material transfer, (b) design transfer, and (c) capacity transfer.[60] And it should also be emphasized that the primary origin of recent international agricultural technology is international agricultural research and development centers such as, for example, the International Rice Research Institute (IRRI) in the Philippines and the International Center for Corn and Wheat Improvement (CIMMYT) in Mexico, founded and supported largely by the United States foundations. This international research and development institute approach clearly represents an effective institutional innovation in the process of international technology research and development and transfer in agriculture as a cooperative endeavor. But, as pointed out already, primarily because of location-specific character of agricultural technology, further adaptive research and development activities must be planned and implemented in respective country in most cases in order to take advantage of new technology internationally transferred, though in some cases such needs might be lessened to some extent by the availability of internationally-oriented research and development efforts. All the developing countries should ultimately be capable of effectively adopting the capacity transfer, in addition to both the material and design transfer. In the case of capacity transfer, the third and final phase in international agricultural technology transfer, the transfer is made through the transfer of scientific knowledge and capacity which enable the production of locally adaptable technology, following the "proto-type" technology which exists abroad. Increasingly, plant and animal varieties are bred

(60) Hayami and Ruttan, *op. cit.*, pp. 174-176.

(61) See, for example: Hayami and Ruttan, *op. cit.*, pp. 182-190; Brown, *op. cit.*, pp. 3-12; German Foundation for Developing Countries, ***Cooperation in Research for Development***, 1972; Theodore Morgan, "Regional Cooperation in Southeast Asia: Problems and Prospects", in ***Agricultural Revolution in Southeast Asia: Impact on Grain Production and Trade, Vol. 1.***, Report of a SEADAG Rural Development Seminar Meeting, Honolulu, June 19-21, 1969, The Asia Society, 1970, pp. 174-193.

locally to adapt them to local ecological conditions. The imported farm machinery designs are modified in order to meet climatic and soil requirements and factor endowments of the respective economy. The developing countries should speed up the entrance into the capacity transfer phase. Naturally, the developing countries must plan and implement effectively and efficiently agricultural "adaptive-," ultimately, "science-oriented" research and development activities.(62) It may be concluded that international technology transfer would be far less meaningful without appropriate national research and development capacity established.

With reference to developing countries, if technological innovation is understood as filling the gap between the technology in practice and the technology which is possible given existing knowledge,(63) then innovations are achieved by well-trained scientists who conduct productive applied research and development activities. But as pointed out before, most developing countries lack high-order skills. In other words, most established institutions in developed countries may have much limitations in supplying research and development needs of developing countries: they could, however, confidently supply knowledge of research and development methodology, scientific procedures, institution-building principles and outcomes of basic research and development with universal application. Since agricultural research and development for developing countries must be specific to local situations, production of appropriate technology should be the most pertinent concern with research and development activities in agriculture of developing countries, primarily based on international technology

(62) Evenson and Binswanger presented implications that although the literature on agricultural research and development policy in the developing countries stresses "technology-oriented" or "A-type" research, the high returns to "science-oriented" or "S-type" research indicate that technological knowledge is not easily transferred internationally. They take this study result as strongly confirming the role of basic and supporting research in generating the potential benefits of applied or adaptive research (Evenson and Binswanger, *op. cit.*, pp. 199-202).

(63) Lewis declared that "...There is always a gap between what is known to the experts to be the most effective way of doing things, and what is actually done by the great majority of people. It is not enough that knowledge should grow; it would also be diffused and applied in practice..."(W. Arthur Lewis, *The Theory of Economic Growth*, Richard D. Irwin, 1954, p. 177).

transfer. Finding, choosing, transferring and developing appropriate technology are crucially important. Eckaus pointed out that there are two aspects of finding technologies adapted to the conditions of developing countries. The first constitutes searching among already known technologies; the second involves research and development to find new technical methods especially suited to the unique conditions of developing countries.[64] This is what we call "choice of technology." Since the relative availabilities of productive resources and factors may vary from country to country and from time to time, the study of appropriate technology must be a continuing program of applied research and development.

From the practical point of view, it would be useful to tackle the problems of research and development needs and methods for finding appropriate technologies. Fundamentally, there may be two approaches for this based on quantitative investigation of alternative technologies in which priority emphasis ought to be pushed toward the more intensive use of the more abundant resources and factors in developing countries and away from the scarce resources and factors. One approach is the investigation of actual production and technological systems which have been or are now in operation and use. The other is the design of alternative production and technological systems. These two approaches are complementary and reinforcing though each has its own set of advantages and disadvantages. The first approach has the special virture of realism. It impels the research and development scientists to consider issues which might otherwise have been passed over. It may also reveal the reflexive or feedback effects of socio-economic forces on the organization of the productive process itself. It requires both inputs and outputs. Real systems, however, always involve adaptations to local conditions and may reflect a quite special set of practices. It may also be difficult first to find and then to measure the inputs and outputs for the variety of technologies in operation and use. This

(64) R.S. Eckaus, "Technological Change in the Less Developed Areas," in Asher *et. al.*, *op. cit.* pp. 120-152.

suggests the advantage in combining such studies with simulation of design of production and technological processes or systems, using different combinations of inputs through international technology transfer. Once a simulation model is set up, it can yield information over a wide range of alternative methods and of alternative employment requirements of various types of skills and various materials, equipment and power inputs. The resulting product is, needless to mention, appropriate technology.

Effective international diffusion or transfer of agricultural technology, furthermore, can be expected to have substantial feedback effects on trade relationships and domestic prices through the operation of international commodity markets. Ruttan and Hayami observed, based on the review of experience of a number of countries over the past century, that developing countries should place greater emphasis on the creation of the capacity of agricultural science and technology to create new and more effective production alternatives than on attempts to achieve a high degree of organization or management of world commodity markets.(65) As already implied, developing countries must take advantage of international transfer of technology for their effective adaptive research and development which lead to rapid agricultural and economic development. But creative or ingeneous capacity for research and development is also quite necessary through "capacity transfer." Consequently, in discussing technology transfer across national boundaries and developing appropriate technology for ultimate "creative technology" in agriculture in developing countries, the problem of the building up of national and indigenous scientific and technological capacity. A developing country without an indigenous scientific and technological capacity in agriculture (and in general) has no means of being aware effectively of its own needs, nor of the opportunities existing in agricultural science and technology elsewhere, nor of the suitability of what is available for its own needs, manifestly and latently or potentially. Thus, far from

(65) Vernon W. Ruttan and Yujiro Hayami, *Technology Transfer and Agricultural Development* Agricultural Development Council, 1973.

being substitutes for each other, the obtaining of agricultural technology from advanced countries and the building up of a national scientific and technological capacity are, in fact, complementary. In this connection, however, it should be pointed out that in some relevant sense, the building up of an indigenous capacity is the primary task of the two.

While there is neither a standard pattern of organization or institutionalization for planning and implementing agricultural research and development policy, nor a standard blueprint of the services and institutions which are needed in each country, some pragmatic generalizations may be possible. First, action to improve national structures of, and remedy weakness in, agricultural research and development, is called for on a country-by-country basis, which, however, exludes neither external aid from bilateral or international sources nor regional action where appropriate. Another generalization would be that the research and development infrastructure in developing countries should be weighted toward the practical problems of production and application rather than toward basic or fundamental work in pure research or science relating to agriculture. The domestic agricultural development infrastructure should include several elements which may be distinguished: (a) effective arrangements for formulating and implementing a national agricultural research and development policy, (b) external or expatriate developmental assistance programs, (c) effective coordination of research and development and extension, (d) institutes for higher education in agricultural sciences, (e) institutions for the training and re-training of scientists and technicians, and (f) institutions to perform research and development work. It would be generally true that compared with the developed countries, the developing countries may generally have serious handicaps in agricultural research and development systems in terms of (a) lack of well-structured organizations, (b) limited numbers of trained research specialists, and (c) program or operational deficiencies. Strengthening national agricultural research and development systems must be implemented and realized, however. But one should not expect to plan for a developing country the total complex and integrated agricultural research and development system that exists in the United States. But Morseman's suggestions in terms of the basic components or elements may be with general implication. They are: (a) a strong national center for background research and for conceptual and coordinating leadership for national and regional projects; (b) regional centers for adaptive research and specialized attention to the agricultural requirements of the major farming regions; and (c) localized research and/or verification and testing stations designed to fit innovations to specific local conditions. In the establishment of this relatively simple pattern of research institutions one should recognize that effective results will be achieved only from research workers with the high levels of skills and training in the respective basic sciences concerned with agriculture.(66) The U.S. and Japanese agricultural research and development systems have been more thoroughly studied than others, and each system successfully responded to the needs of farmers and contributed to agricultural and economic development.(67) But whether the U.S. and Japanese experiences provide models for the developing countries is an open question, indeed.(68)

The success of the agricultural development research effort will depend on the ability of the coordinator or administrator to bring together a trained group of research specialists that will function as an interdisciplinary task force with sufficient capability to cope with the multiplicity of agricultural research and development problems in research institutions. In this connection, however, the

(66) Albert H. Morseman, "Research Systems," in Melvin G. Blase, ed., *Institutions in Agricultural Development*, Iowa State University Press, 1971, pp. 139-148; *Building Agricultural Research Systems in the Developing Nations*, The Agricultural Development Council, 1970; D. Woods Thomas *et al.*, eds., *Institution Building: A Model for Applied Social Change*, Schenkman Publishing Company, 1972.

(67) Heady implied that successful government investment in agricultural research and development and extension has been showing high pay-off for many countries; two typical countries are USA in the Western World and Japan in the Eastern World (Early O. Heady, *Agricultural Policy under Economic Development*, Iowa State University Press, 1969, p. 602).

(68) Thomas M. Arndt and Vernon W. Ruttan, *Resource Allocation and Productivity in National and International Agricultural Research* (seminar report), The Agricultural Development Council, 1975.

stress on coordinated or directed national research programs in a sense alters what type of research and development institute works best in a developing country. Many types of institutions can be productive if integrated (coordinated) effectively around specified national/regional research goals. But there is still a question: can a research and development system continue to be productive if its direction continues to come primarily from the center? Gable and Springer observed that some types of research can be better conducted in well-equipped and -staffed central research stations, while others require on-the-site experimentation in individual farming areas, and that depending on the circumstances, it may be desirable for some research to be conducted within a college or university. Furthermore, they conclusively implied that ideally, all agricultural research and development activities should be articulated into a national system, whether it is supported entirely by government or in part by the private sector, to assure the most widespread utilization and dissemination of the research and development products.(69) Hayami implied that the experience of Japan is relevant with respect to the increases in the rate of social return to research and development investment corresponding to the re-organization of the rice-breeding research and development system, or institutional change for agricultural research and development.(70)

V. Concluding Remarks

In this paper, (a) an introductory note on the agriculture's role in national development, (b) technological change and agricultural development, (c) agricultural research and development and social returns, and (d) technology transfer and developing appropriate technology, have been generally examined and described with special reference to developing countries in general. As we appreciate very well, the developing countries have too much variations and differ-

(69) Richard W. Gable and J. Fred Springer, *Administering Agricultural Development in Asia: A Comparative Analysis of Four National Programs*, Westview Press, 1976, p. 55.

(70) Hayami, *op. cit.*, p. 165.

ences in technical and nontechnical aspects of agriculture in accordance with "antecedents" and national developmental stages to be generalized simply in one category. The so-called "ideal-type" approach has been adopted consequently in this general paper. Though implicitly implied, many developing countries in this particular region or others have had coloninal experiences whose deep-rooted direct and indirect impacts seem to be so greatly felt in the field of research and development for agricultural innovations for agricultural development, not to mention other almost all aspects of national developmental life. But relatively considerable time has passed for most developing countries since their independence which should imply that national self-generating efforts for agricultural research and development have been planned and implemented under severe limiting factors and conditions primarily with the international agricultural technology transfer with a view to facilitating agricultural and economic development. Bilateral agricultural technical assistance programs, notably those by the United States government and others have had historically and initially profound impacts even with some dysfunctional "cultural shocks" on the recipient developing countries in research and development activities and agricultural development in general. It would be true that many trial-and-error type unsuccessful experiences witnessed come from the so-called "direct technology transfer" in international settings. But fortunately, international agricultural research and development centers such as CIMMYT and IRRI have been developed to render significant contributions to the agricultural development through relatively adapted agricultural technology research and development activities.

The usually significant social returns or dividends of research and development in agriculture have been amply demonstrated economically and noneconomically, which have also significant impact upon general economic and national development in developing countries. The so-called "green revolution" would be the very example which has also serious disadvantages and problems usually dubbed as the "second-generation problems". Transfer of international agricultural technology in general and that of major international agricultural research and development centers cannot be directly applied to each developing country to suit its location-specific conditions and factors. Moreover, the positive fruits of international technology transfer as successfully transformed and adapted to local conditions, commonly represented by the increased productivity or increased quantity of production for a particular agricultural commodity may have an economically serious impact upon international commodity trade. Therefore, each developing country must become capable of conducting "creative" or innovatively indigenous research and development activities, in addition to the traditional "adaptive" research and development ones, in this context, through international technology transfer. As in the case of industry, indigenous innovations must be made available through national agricultural research and development activities in agriculture, too.

The national effective institution-building for agricultural research and development in a developing country should be so much challenging, largely because of so many complementary and reinforcing variables of technical and non-technical, and basic and applied, nature within the framework of national development, not to mention the severe resource constraints. But it is a must simply because we know the pole of the research and development activities in agriculture for agricultural and general economic development. Here it is assumed that, in addition to the typical international technology transfer, developing countries in a particular region may need cooperation among themselves.[71] In the case of Korea, agricultural research and development system-building has been developed relatively successfully under the very much strong impacts of the two world-wide most successful countries of agricultural research and development, Japan and the United States. The core of the research and

(71) Morgan aptly tackled regional cooperation for agricultural development among developing countries in Southeast Asia (Theodore Morgan, "Regional Cooperation in Southeast Asia: Problems and Prospects," in ***Agricultural Revolution in Southeast Asia....***, ***op. cit.***, pp. 174-193). Hews also discussed this matter (Hews, *op. cit.*, pp. 130-143).

development institution-building for agriculture and any other endeavors is, needless to point out, to secure competent research and development specialists. For this, personnel training programs should be actively planned and implemented "within" and "between" developing countries as well as developed countries. The interdisciplinary nature of agricultural research and development must not be lost in sight. At the same time, it should be kept in mind that effective resource allocation and favorable "social climate" do matter significantly for agricultural research and development activities in a developing country. And, most of all, the role and impact of research and development, consequently, technological change in agriculture, should be understood as very extensive and deep in its scope even within the agricultural sector only.[72]

In conclusion, it would be imperative that each developing country must do its best for agricultural research and development by being keenly aware of the fact that (a) the role of agricultural research and development is positively significant not only for agricultural technological change and development but also for general economic and national development (leading to industrialization); and (b) national agricultural research and development system must be effectively and innovatively evolved so that it could not only take advantage of international agricultural technology transfer of interdisciplinary nature but also reach the so-called "capacity phase" in which creative and innovatively indige-

(72) See, for example, the following with respect to the impact of modern agricultural technology change within agricultural sector, especially on rural life in Asian countries: Cheng-hung Liao and Martin M.C. Yang, "Socio-economic Change in Rural Taiwan: 1950-78", *Southeast Asian Studies*, Vol. 18 (March 1981), pp. 539-566; Moon Shik Kim and Nai Won Oh, "Technical Change and Rural Development in Korea: 1967-76," *Southeast Asian Studies*, Vol. 18 (March 1981), pp. 567-586; L.J. Fredericks, "Ecology, New Technology, and Rural Development: Impressions of Kampung Ulu Triram Burok," *Southeast Asian Studies*, Vol. 18 (March 1981), pp. 587-605; Kamphol Adulavidhya and Suwanna Toeetharat, "The Adoption of New Rice-growing Techniques in Central Plain: Thailand," *Southeast Asian Studies*, vol. 18 (March 1981), pp. 606-611; Gelia Tagumpay-Castillo, "Impact of Agricultural Innovation on Patterns of Rural Life (Focus on the Philippines)" in *Agricultural Revolution in Southeast Asia: Consequences for Development, Vol. II*, Report of the Second SEADAG International Conference on Development in Southeast Asia, New York, June 24-36, 1969, The Asia Society, pp. 13-52.

nous research and development activities in agriculture are effected.[73]

(73) I would strongly suggest to pay special attention to the experience of Korea, one of the leader developing countries in the region in her successful research and development activities in agriculture with special reference to the role and institution-building of the Office of Rural Development (ORD) a giant outside research and extension arm of the Ministry of Agriculture and Fisheries (MAF) of Korea. (See, for example, ***An Introduction to the Rural Development Program***, Office of Rural Development, 1980). For example, social returns to the research and development of the Korean-version HYV of rice, "Tongil" by the Office of Rural Development, was estimated at 1,210% in 1977. In this connection, however, after 1977, the so-called "second-generation problems" crippled the green revolution in Korea, primarily because of the biological susceptibility to (a) disease, and (b) cold temperature (see, Ki Hyuk Park, ***Noksaek Hyukmyung eui Kyungje Sahoejuck Hyokwa Bunsuck*** (An Analysis of Socio-economic Effects of Green Revolution—Development and Dissemination of Tongil Rice Variety), 1977, Yeonse University).