

*Lectures in Development Economics*  
*No. 6*

**VERNON W RUTTAN**

**Lectures on  
Technical and Institutional  
Change In  
Agricultural Development**

*with comments by*  
**Syed Nawab Haider Naqvi**

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**Biographical Sketch**

VERNON W. RUTTAN is a faculty member of the University of Minnesota (USA) where he has been Professor of Economics since 1965 and Professor of Agricultural and Applied Economics and Professor at the Hubert H. Humphrey Institute of Public Affairs since 1978. Born at Alden (Michigan) on August 16, 1924, Professor Ruttan received his baccalaureate from Yale University in 1948 and his Master's and Doctor's degrees from the University of Chicago in 1950 and 1952 respectively.

An acknowledged authority on Agricultural Economics, Professor Ruttan has authored two books and co-authored another three books. He has also edited five books. He has already published more than 60 articles in a number of reputable international journals besides contributing nearly 50 chapters to books and conference proceedings, and producing 16 monographs and bulletins. Professor Ruttan's main interests include agricultural policy, innovation and technological change, agricultural pricing and marketing, agrarian reform, transfer of agricultural technology, and integrated rural development. His outstanding research has earned him a number of honours and awards.

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## INTRODUCTION TO THE SERIES

The purpose of this new Series is to create useful knowledge about development economics and to disseminate it widely. It is not possible to prescribe exactly the topics that will be discussed in this Series. Indeed, it would not even be desirable to do so because this subject is still developing. The mystery of the development process is not yet fully understood. The days of chivalry, when economic development was seen as simply a function of physical capital formation, are gone. The importance of such factors as human capital, education and religion as determinants of both the rate and the composition of economic growth is now gradually recognized. And then there are the efforts to understand more clearly the relationship between economic growth and income distribution. In this connection, the vital role of structural reform is also being realized. The practical (social and political) requirement of alleviating the incidence of absolute poverty has brought to the fore the key role of agricultural development. Furthermore, there is now a greater awareness of the importance of endogenizing the demographic variables in order to understand fully the problem of underdevelopment as well as the many ways of solving it.

In direct proportion to the comprehension of these issues, the intellectual fashions have changed among economists. And there are no signs — a healthy sign, of course — that economists will remain far behind ladies in their love for fashion. As such, we have left it to the contributors to this Series to decide on the topics of their lectures. And, yet, it is to be expected that economists, as if guided by an 'invisible hand', will select areas of enquiry that are most relevant not only theoretically but also for practical policy making.

The contributors to this Series are all members of the Advisory Board of the Pakistan Institute of Development Economics (PIDE) and of the Editorial Board of the *Pakistan Development Review*. The visits of these outstanding economists have been made possible by a generous grant by the Ford Foundation, which is administered by the Institute of International Education (IIE), New York. It is to be hoped that the success of this Series, which we can predict with certainty, will lead to greater financial support from the Ford Foundation and other donor agencies. Even more important is the 'fact' that these contributions will serve the cause of knowledge formation in an area where its marginal productivity is most likely to be optimized.

The present lecture by Prof. Vernon W. Ruttan is the sixth in the series. Prof. Ruttan, a member of the International Editorial Board of the PIDE, is an outstanding authority in the general area of Agricultural Economics. It is in this area that his intellectual contributions are most noteworthy. The two lectures reproduced here, along with the lively discussion that followed, should be of great interest to academic economists and also to policy-makers. It is hoped that this publication will be read with interest by the concerned social scientists throughout the world.

*Editor*



**INTRODUCTORY  
REMARKS**

*by*

**Professor Syed Nawab Haider Naqvi**

## INTRODUCTORY REMARKS

*by*

Professor Syed Nawab Haider Naqvi

Professor Ruttan, distinguished guests, ladies and gentlemen:

Following a year-and-a-half-old custom, I would introduce today's speaker before the substantive proceedings of the session start. I will try to give you in the next fifteen minutes or so a brief overview of Prof. Vernon W. Ruttan's thinking in the general area of agricultural economics.

Let us first look at the man himself. As if to launch a three-pronged 'attack' on agricultural economics, Prof. Ruttan is at present strategically placed as Regents Professor at the University of Minnesota, with appointments in the Department of Agricultural and Applied Economics and the Hubert Humphrey Institute of Public Affairs. Being one of the most outstanding persons in the field of agricultural economics, Prof. Ruttan deserves nothing less. To reach his present position of eminence, he had to travel a long way. Working his way up from the grassroots — his first professional appointment (1951) was with the Tennessee Valley Authority — Prof. Ruttan never settled for anything but the 'first best' in the economics profession. He has held eminent government positions, and has headed distinguished research institutions in the United States as well as in many developing countries like the Philippines. To learn the subject really well, he has variegated his academic life with both the chemistry and the economics of agriculture.

Born in 1924 on a 120-acre farm in Michigan\*, he has always remained loyal to the farm: he is literally a true son of the soil. He has devoted almost all his productive life to agriculture; since he is not a demographer, let me not mention the reproductive part of his life. The professional community has, from time to time, shown admiration for his intellectual odyssey. He was President of the Agricultural Development Council from 1973 to 1978, and was elected President of the Agricultural Economics Association from 1971 to 1972. He was awarded an (honorary) LL. D. in 1978 by Rutgers University; and, more recently (1984), he won the prestigious Alexander von Humboldt Award. He is also listed in Mark Blaug's highly selective *Who's Who in Economics*.<sup>1</sup>

Ever since he set eyes on the subject, Prof. Ruttan has not given agricultural economics a moment's rest. So far he has made 250 contributions in the general area of agricultural economics. He has written 5 books, and edited 5 volumes on various aspects of agricultural economics.<sup>2</sup> In addition, he has contributed 38 research articles to most of the top professional journals like the *Journal of Agricultural Economics*, the *Journal of Political Economics*, the *Quarterly Journal of Economics*, the *American Economic Review*, the *Pakistan Development Review* and many others. In addition, he has made 46 contributions to books and conference proceedings, and produced 16 monographs and bulletins, 61 notes and comments and reviews, 14 public documents and committee reports, and 59 miscellaneous articles of a "semi-popular kind".

This is a massive intellectual outpouring by any standard; and, speaking agriculturally, it bespeaks a highly fertile mind. But even more striking than the number is the brilliant quality of the books and papers that he has published. Among his many books and articles are some that

\*See his Biographical Sketch, reproduced as Appendix to the present volume.

<sup>1</sup>Mark Blaug and Paul Sturgis. *Who's Who in Economics: A Biographical Dictionary of Major Economists: 1700-1981*. Cambridge: The MIT Press. 1983.

<sup>2</sup>His main books (written by him alone or jointly with others) are three, and a fourth one is in an advanced stage of preparation. The three main books are:

- (i) *Agricultural Research Policy*. Minneapolis: University of Minnesota Press. 1982.
- (ii) *Agricultural Development: An International Perspective*. With Yujiro Hayami. 2nd Edition. Baltimore: The Johns Hopkins University Press. 1985.
- (iii) *Induced Innovation: Technology, Institutions and Development*. With Hans P. Binswanger and others. Baltimore: The Johns Hopkins University Press. 1978.

have been rightly ranked by the profession as "classic" and "path breaking". I will now give you a brief outline of his seminal contributions to the subject.

Paul Samuelson remarked that the quality of a top scientist is established by his early work. Judged by this criterion, Prof. Ruttan qualifies as one of the top agricultural economists. Even as a budding economist he showed a clear understanding of the roles of relative factor and product prices as well as of technological change: in determining agricultural output. And in the manner of a fervid existentialist, he set about, very early in his career, turning technological change from the status of an "outsider" to that of an insider in the process of agricultural growth. These were key insights that served to illuminate large areas of economics engulfed in the foggy twilight of the agricultural sector. By combining *a priori* reasoning with empirical testing and verification to establish his basic propositions, Prof. Ruttan has left no stone unturned to bring *agricultural* economics, through his many-splendoured contributions, into the warm glow of the *culture* of economics. With a 'touch of class', he has sought indefatigably to weave many diverse themes into a recognizable pattern that features a country's resource endowments, factor and product prices, technological change, and institutional change as interacting with each other and influencing the time path of agricultural productivity and growth.

But let me go over Prof. Ruttan's 'discoveries' more slowly, in a chronological order. He wrote his first two classics soon after doing his Ph.D. in 1952? In the first paper, (written in 1955) which won for him the American Farm Economics Association Award in 1956, Prof. Ruttan tested the Schultz. "impact hypothesis". He posits a (causal) relationship between industrial-urban development and that part of the agricultural sector which is located in the vicinity of urban 'growth poles'. This work has helped him, and many others, in understanding the mystique of the process of agricultural development, wherein are identified those crucial relationships between the farm and non-farm sectors which are seen as

<sup>3</sup>"The Impact of Urban-Industrial Development on Agriculture in the Tennessee Valley and the Southeast". *Journal of Farm Economics*. Vol. 37. February 1955; reprinted in Karl A. Fox and D. Gale Johnson, *Readings in the Economics of Agriculture*. Homewood: Richard D. Irwin. 1969.

strung together through *factor markets* — especially the labour market. A clear understanding of these linkages has figured prominently in his subsequent writings and has helped him to look at agricultural growth as taking place within the matrix of a growing economy and not as an isolated event.<sup>4</sup> Prof. Ruttan struck again a year later (in 1956), when his second seminal contribution was made.<sup>5</sup> From the vantage point of his later work on induced technological change, this paper was of fundamental importance. It successfully attempted to measure, within a non-linear production-function framework, the contribution of technological progress to the secular increases in per acre productivity and agricultural output in the USA. This paper, too, won a research award from the American Farm Economics Association in 1957. Both these papers, besides providing analytical frameworks for analysing the various causatory factors in promoting agricultural growth and productivity, also generated a wealth of data on the relevant variables — and also secured a (small) part of the 'wealth of nation' for Prof. Ruttan's pocket as prize money.

These early ideas were further refined and developed in two of his highly influential papers that appeared in the *Journal of Political Economy (JPE)*<sup>6</sup> and the *American Economic Review (AER)*<sup>7</sup>, both in 1970. The *JPE* paper attempted, with success, to explain the phenomenon of "high and sustained rates of agricultural growth", despite observed wide inter-country differences (between the USA and Japan) in factor endowments and factor price ratios, by reference to the ability of each country "to generate a continuous sequence of induced innovations in agricultural technology biased toward saving the limiting factors". The demonstration of this important hypothesis, which *sounds* very much like the celebrated Heckscher-Ohlin Theorem, established Ruttan's

<sup>4</sup>On this theme he wrote, much later, in his *Agricultural Research Policy* (Minneapolis: University of Minnesota Press, 1983): "The problem of agricultural development is . . . one of accelerating the rate of growth in agricultural output and productivity consistent with the growth of other sectors in a modernizing economy."

<sup>5</sup>"The Contribution of Technological Progress to Farm Output: 1950-1975". *Review of Economics and Statistics*. Vol. 38. February 1956.

<sup>6</sup>"Factor Prices and Technological Change in Agricultural Development: The United States and Japan, 1880-1960". *Journal of Political Economy*. September-October 1970.

<sup>7</sup>"Agricultural Productivity Differences Among Countries". *American Economic Review*. December 1970.

induced-innovation hypothesis. The novelty of this hypothesis is that, unlike the neo-classical tradition of considering technical change as exogenously determined, it treats it as *endogenous* to the process of agricultural development.<sup>8</sup> This hypothesis, in turn, illustrates clearly the fundamental point about the dynamics of agricultural growth: there is a unique agricultural growth-path for each country, and the differences between such 'optimal' growth paths are explained by a dynamic adjustment in input mixes to changes in relative factor prices reflecting resource endowment patterns of different countries.

The *AER* paper brought out clearly Prof. Ruttan's ideas on the sources of inter-country differences (between the developed and developing countries) in labour productivity — i.e. output per male worker — in 1960. Using a production function of the Cobb-Douglas type it showed that the "critical element" in explaining productivity differences between the developed and developing countries was overwhelmingly related to differences in "the supply of modern industrial inputs" (viz. fertilizer and machinery) and "investment in general education and in research and extension", and only marginally to differences in land-labour ratios. The study pointed out clearly the need for making, in the developing countries, substantial investments in rural education and in physical and biological sciences.

This last observation has led Prof. Ruttan to emphasize his third basic idea: the centrality of a proper *institutional* framework for promoting the 'right' type of research policy. This theme has been explained clearly in one of his recent books, which also brings together his thinking on the three themes that I have just recounted.<sup>9</sup> Prof. Ruttan's emphasis on scientific research, *within the framework of public research institutions*, has led him to formulate his fourth hypothesis relating (induced) institutional change to (induced) technological change. While technological change creates *demand* for new knowledge about the institutional dimensions of agricultural and development process, institutional change *supplies* that knowledge.

<sup>8</sup>The theme of induced innovation was more fully developed in *Induced Innovation: Technology, Institutions and Development*. (Baltimore: Johns Hopkins University Press. 1978), which he co-authored with Hans P. Binswanger and others. The hypothesis was empirically tested against the experience of both the developed and the developing countries.

<sup>9</sup>*Agricultural Research Policy*. Minneapolis: University of Minnesota Press. 1983.

Through his long and distinguished career as a researcher and (academic) administrator, the four above-mentioned themes, all highly relevant and revealing, have been elaborated and refined and their applications have been drawn from both the developed and the developing countries.<sup>10</sup> In the process of doing his research, he has generated a wealth of time-series data for long periods of time — for one hundred years (from 1883 to 1983) in the case of the USA and Japan - on factor prices and product prices and on other variables relevant for understanding the process of technological change and agricultural development. In this respect, Prof. Ruttan's work is in the tradition of Simon Kuznets.

His work is also rich in terms of its policy implications. For instance, he recommends that the developing countries should make a shift from a resource-based agriculture to a science-based agriculture with a view to ensuring a sustained agricultural growth in the long run. But to make such a shift, technological innovation must be evolved *domestically* by government-sponsored scientific research institutes, in response to secular changes in relative factor (input) prices. In this connection he emphasizes the need for explaining the mechanism whereby resources get allocated to education and research; specifically to basic research in agriculture. He pinpoints two basic policy issues. In the first place, when it comes to doing basic scientific research on agriculture, the invisible hand of the market has at best a limited role. He makes the important observation that ". . . the progress of agricultural technology [cannot] be left to an 'invisible hand' — to the undirected market forces that will direct technology along an 'efficient' pattern determined by the 'original' resource endowment or relative factor and product prices."<sup>11</sup> Accordingly, he advocates "socialization" of agricultural research, especially in the developing countries where proper institutional frameworks still remain to be created. Secondly, Prof. Ruttan notes that borrowed technology may take one part of the way, but not all the way. "Those countries that have attempted to rely primarily on borrowed technology have rarely developed the capacity to adopt and manage the borrowed

<sup>10</sup>His close association in the mid-Sixties with the biological science programme at the International Rice Institute in the Philippines has been especially helpful in clearly identifying the processes by which technological change is developed and diffused.

<sup>11</sup>*Agricultural Research Policy*, *ibid.* p. 41.

technology in a manner capable of sustaining agricultural development."<sup>12</sup> Developing countries like Pakistan are well-advised to take these observations seriously.

The temptation is great to get carried away and give a lecture on Prof. Ruttan's work, but I must resist the temptation, if only because of the time constraint, which is (morally) binding even on the chairman. I would now request Prof. Ruttan to start his lecture on "Technical Change and Agricultural Development".



*Lecture I*

**TECHNICAL CHANGE  
AND AGRICULTURAL  
DEVELOPMENT**

*Lecture I\**

**TECHNICAL CHANGE AND  
AGRICULTURAL DEVELOPMENT**

Professor Naqvi, Dr Sarfraz Qureshi, and distinguished guests:

We are, in the closing years of the twentieth century, completing one of the most remarkable transitions in the history of agriculture. Prior to this century, almost all the increase in food production was obtained by bringing new land into production. There were only a few exceptions to this generalization — in limited areas of East Asia, in the Middle East, and in Western Europe. By the end of this century, almost all of the increase in world food production must come from higher yields — from increased output per hectare. In most of the world, the transition from a resource-based to a science-based system of agriculture is occurring within a single century. In a few countries, this transition began in the nineteenth century. In most of the currently developed countries it did not begin until the first half of this century. Most of the countries of the developing world have been caught up in the transition only since mid-century.

\*This and the following lecture were presented at the Pakistan Institute of Development Economics on January 2 and 3, 1985. The two lectures draw on and extend material that appears in Chapter 3, "Theories of Agricultural Development," and Chapter 4, "On Induced Innovation Theory of Agricultural Development" in the forthcoming book by Yujiro Hayami and Vernon W. Ruttan, *Agricultural Development: An International Perspective* (Johns Hopkins University Press, 1985). See also Hans P. Binswanger and Vernon W. Ruttan (with others), *Induced Innovation: Technology, Institutions and Development* (Baltimore: The Johns Hopkins University Press, 1978); Yujiro Hayami and Masao Kikuchi, *Asian Village Economy at the Crossroads: An Economic Approach to Institutional Change* (Tokyo: University of Tokyo Press, 1981 and Minneapolis: University of Minnesota Press, 1982), and Vernon W. Ruttan and Yujiro Hayami, "Toward A Theory of Induced Institutional Innovation". *The Journal of Development Studies* (July 1984). pp. 203-223.

## MODELS OF TECHNICAL CHANGE IN AGRICULTURE

The traditional literature on agricultural development can be classified under five general headings. These are (1) the resource exploitation, (2) the conservation, (3) the location, (4) the diffusion, and (5) the high-payoff input models.

### **The Resource Exploitation Model**

Throughout most of history, expansion of the area cultivated or grazed has represented the dominant source of increase in agricultural production. The most dramatic example in Western history was the opening up of the new continents — North and South America and Australia — to European settlement during the eighteenth and nineteenth centuries. With the advent of cheap transport during the latter half of the nineteenth century, the countries of the new continents became increasingly important sources of food and agricultural raw materials for the metropolitan countries of Western Europe.

Similar processes had occurred earlier, though at a less dramatic pace, in the peasant and village economies of Europe, Asia, and Africa. The agrarian colonization of the Indus and Ganges river valleys occurred in the third millennium B.C. The first millennium A.D. saw the agricultural colonization of Europe north of the Alps, the Chinese settlement of the lands south of the Yangtze, and the Bantu occupation of Africa south of the tropical forest belt. Intensification of land use in the existing villages was followed by pioneer settlement, the establishment of new villages, and the opening up of forest or jungle land to cultivation. In Western Europe, there was a series of successive changes from neolithic forest fallow to systems of shifting cultivation of bush and grassland, followed, first, by short fallow systems and, later, by annual cropping.

Where soil conditions were favourable, as in the great river basins and plains, the new villages gradually intensified their systems of cultivation. Where soil resources were poor, as in many of the hilly and upland regions, new areas were opened up to shifting cultivation or nomadic grazing. Under conditions of rapid population growth, the limits to the resource exploitation model were often quickly realized. Crop yields were typically low — measured in terms of output per unit of seed rather

than per unit of cropped area. Output per hectare and per man-hour tended to decline — except in the delta areas of Egypt and South Asia and in the wet rice areas of East Asia. In many areas the result was an increasing immiserization of the peasantry.

Agriculture carried on within the framework of the resource exploitation model was, in most parts of the world, capable of supporting only very limited urban concentrations — trading centres and seats of government. Most food was consumed in the village in which it was produced. Much of the surplus that did become available was extracted from the village by landlords in the form of rents, and by the church in the form of tithes. The limited surplus that could be accumulated exerted a decisive impact on political organizations. The military campaigns that Charlemagne waged against the Germans to extend his Frankish Kingdom could not be waged until early summer. The great heavy horses that carried his armed knights had to be out on grass long enough, after a winter on poor feed, to get in condition.

There are relatively few remaining areas of the world where development along the lines of the resource exploitation model will represent an efficient source of growth during the last two decades of the twentieth century. The 1960s saw the "closing of the frontier" in most areas of Southeast Asia. In Latin America and Africa the opening up of new lands awaits development of technologies for the control of pests and diseases (such as the tsetse fly in Africa) or for the release and maintenance of productivity of problem soils. The decline in food production that has been experienced in many African countries over the last several decades is an insistent reminder that agricultural growth along the lines described by the resource exploitation model is no longer a reliable source of growth in food production.

#### The Conservation Model

The conservation model of agricultural development evolved from the advances in crop and livestock husbandry associated with the English agricultural revolution and the notions of soil exhaustion suggested by the early German chemists and soil scientists. It was reinforced by the application to land of the concept, developed in the English classical school of economics, of diminishing returns to labour and capital.

Until well into the twentieth century, the conservation model of agricultural development was the only approach to intensification of agricultural production available to most of the world's farmers. Its application is effectively illustrated by the development of the wet-rice culture systems that emerged in East and Southeast Asia and by the labour- and land-intensive systems of integrated crop — livestock husbandry which increasingly characterized European agriculture during the eighteenth and nineteenth centuries.

During the English agricultural revolution, more intensive crop-rotation systems replaced the open three-field system in which arable land was allocated between permanent cropland and permanent pasture. This involved the introduction and more intensive use of new forage and green manure crops and an increase in the availability and use of animal manures. This "new husbandry" permitted the intensification of crop — livestock production through the recycling of plant nutrients, in the form of animal manures, to maintain soil fertility. The inputs used in this conservation system of farming — the plant nutrients, animal power, land improvements, physical capital, and agricultural labour force — were largely produced or supplied by the agricultural sector itself.

Agricultural development, within the framework of the conservation model, clearly was capable in many parts of the world of sustaining rates of growth in agricultural production in the neighbourhood of 1.0 percent per year over relatively long periods of time. The most serious recent effort to develop agriculture within this framework was made by the People's Republic of China in the late 1950s and early 1960s. It became readily apparent, however, that the feasible growth rates, even with a rigorous recycling effort, were not compatible with modern rates of growth in the demand for agricultural output — which typically fall in the 3—5 percent range in the less developed countries (LDCs). The conservation model remains an important source of productivity growth in most of the poor countries and an inspiration to agrarian fundamentalists and the organic farming movement in the developed countries.

### **The Location Model**

Initially, the location model was formulated in Germany by J. H. von Thiinen to explain geographic variations in the intensity of farming

stems and the productivity of labour in an industrializing society. In the United States it was extended to explain the more effective performance of the input and product markets in regions of rapid urban-industrial development than in regions of slower urban-industrial development. In the 1950s, interest in the location model reflected concern with the failure of agricultural resource development and price policies, adopted in the 1930s, to remove the persistent regional disparities in agricultural productivity and rural incomes in the United States.

The rationale for this model was developed in terms of more effective input and product markets in areas of rapid urban-industrial development. Industrial development stimulated agricultural development by expanding the demand for farm products, supplying the industrial inputs needed to improve agricultural productivity, and drawing away surplus labour from agriculture. The empirical tests of the location model have confirmed repeatedly that a strong non-farm labour market is a prerequisite for labour productivity in agriculture and improved incomes for rural people.

The policy implications of the location model appear to be most relevant for less developed regions of highly industrialized countries or lagging regions of the more rapidly growing LDCs. Agricultural development policies based on this model appear to be particularly inappropriate in those countries where the "pathological" growth of urban centres is a result of population pressures in rural areas running ahead of employment growth in urban areas.

#### The Diffusion Model

The diffusion of better husbandry practices was a major source of productivity growth even in pre-modern societies. The diffusion of crops and animals from the new world to the old — potatoes, maize, cassava, rubber — and from the old world to the new — sugar, wheat, and domestic livestock — was an important byproduct of the voyages of discovery and trade from the fifteenth to the nineteenth centuries.

Diffusion of crops and animals had historically proceeded as a byproduct of trade, discovery and migration. The diffusion of maize to the Old World is an example. Within a decade after Columbus had first

displayed Indian corn (maize) at the Spanish court, it was being grown in the Po Valley in Northern Italy. In that relatively short time, it had diffused from Spain and across North Africa to Turkey and was brought to the Po Valley by Venetian traders.

By the latter part of the nineteenth century, all major agricultural nations were actively engaged in organized crop exploration and introduction. The famous trip of Captain Bligh to the South Pacific, described in the book and the film, *Mutiny on the Bounty*, was undertaken as a crop exploration mission. His assignment was to bring back breadfruit seedlings and wild sugar-cane cultivars. But his crew was more attracted to brown girls.

The botanical gardens established by the great colonial powers were primarily meant to serve as crop introduction stations. The diffusion of rubber from Brazil to Southeast Asia illustrates their role. When the process of vulcanization was invented — making it possible to produce such desirable products as rubber boots, raincoats and tyres — the price of natural rubber, produced from wild trees in the Amazon basin of Brazil, skyrocketed. Brazil made it illegal to export either rubber seeds or rubber plants. The British sent a botanical expedition to Brazil with the ostensible purpose of collecting plants that had medicinal value. But they also brought back rubber seeds. The seeds were first sprouted at the Royal Botanic Gardens at Kew. The seedlings were then transferred to the botanical gardens at Kandy (Sri Lanka) and in Singapore. The Kandy seedlings died but the Singapore seedlings lived and became the foundation stock of the rubber industry in Southeast Asia.

In the early post-World-War-II period, the diffusion model provided the intellectual foundation for technical assistance to developing countries. President Truman talked about American "knowhow — show-how." The naive diffusion-approach drew on the empirical observation of substantial differences in land and labour productivity among farmers and regions. The route to agricultural development in this view was through more effective dissemination of technical knowledge and the narrowing of productivity differences.

The diffusion model has provided the major intellectual foundation of much of the research and extension effort in farm management and production economics since the emergence, in the later years of the

nineteenth century, of agricultural economics and rural sociology as separate subdisciplines linking the agricultural and the social sciences. Developments leading to the establishment of active programmes of farm management research and extension occurred at a time when experiment station research was making only a modest contribution to agricultural productivity growth. A further contribution to the effective diffusion of known technology was provided by rural sociologists' research on the diffusion process. Models were developed emphasizing the relationship between diffusion rates and the personality characteristics and educational accomplishments of farm operators.

Insights into the dynamics of the diffusion process, when coupled with the observation of wide agricultural productivity gaps among developed and less developed countries and a presumption of inefficient resource-allocation among "irrational, tradition-bound" peasants, produced an extension or diffusion bias in the choice of agricultural development strategy in many LDCs during the 1950s. During the 1960s, the limitations of the diffusion-of-technology-transfer model as a foundation for the design of agricultural development policies became increasingly apparent as technical assistance and rural development programmes — based explicitly or implicitly on this model — failed to generate either rapid modernization of traditional farms and communities or rapid growth in agricultural output. There were very few opportunities to generate large productivity gains through the transfer of technology from one agroclimatic zone to another, or even among regions in the same agroclimatic zone. The pipeline was empty!

#### The High-Payoff Input Model

The inadequacy of policies based on the conservation, urban-industrial impact, and diffusion models led, in the 1960s, to a new viewpoint: the key to transforming a traditional agricultural sector into a productive source of economic growth in investment, designed to make modern, high-payoff inputs available to farmers in poor countries. Peasants in traditional agricultural systems were viewed as rational, efficient resource-allocators.

In *Transforming Traditional Agriculture*, T. W. Schultz insisted that peasants in traditional societies remained poor because there were only limited technical and economic opportunities to which they could



respond. The new, high-payoff inputs were classified into three categories according to (i) the capacity of public- and private-sector research institutions to produce new technical knowledge; (ii) the capacity of the industrial sector to develop, produce, and market new technical inputs; and (iii) the capacity of farmers to acquire new knowledge and use new inputs effectively.

The enthusiasm with which the high-payoff input model has been accepted and translated into economic doctrine has been due in part to the proliferation of studies reporting high rates of return to public investment in agricultural research (Table 1). It was also due to the success of efforts to develop new, high-productivity grain varieties suitable for the tropics. New, high-yielding wheat varieties were developed in Mexico beginning in the 1950s, and new, high-yielding rice varieties were developed in the Philippines in the 1960s. These varieties were highly responsive to industrial inputs such as fertilizer and other chemicals and to more effective soil and water management. The high returns associated with the adoption of the new varieties and the associated technical inputs and management practices have led to a rapid growth in investment in agricultural research and to the development and adoption of the new and more productive crop varieties by farmers in a number of countries in Asia, Africa, and Latin America.

But the acceptance of the high-payoff input model has been incomplete. Many countries have not yet freed their private sector to produce and market the new technical inputs which enhance productivity. Those are the functions which the public sector typically performs poorly. The constraints placed on market development continue to deprive farmers and consumers of gains from the new technology that is becoming available.

There has been even greater reluctance, in a number of developing countries, to accept the implication of the high-input model for the schooling of farm people. The intellectuals and planners in many developing countries find it difficult to understand the importance, for agricultural development, of a literate and a numerate peasantry. When advances in agricultural technology occurred slowly, the apprenticeship mode of learning, without formal schooling, from family and village elders was adequate. But when a continuous stream of new biological

Table 1

*Summary of Studies on Agricultural Research Productivity*

Study	Country	Commodity	Time Period	Annual Internal Rate of Return(%)
<b>Index Number</b>				
Griliches, 1958	USA	Hybrid corn	1940--1955	35-40
Griliches, 1958	USA	Hybrid sorghum	1940--1957	20
Peterson, 1967	USA	Poultry	1915--1960	21-25
Evenson, 1969	S. Africa	Sugar-cane	1945--1962	40
Barletta, 1970	Mexico	Wheat	1943--1963	90
Barletta, 1970	Mexico	Maize	1943--1963	35
Ayer, 1970	Brazil	Cotton	1924--1967	77+
Scimitz and Seckler, 1970	USA	Tomato harvester, with no compensation to displaced workers	1958--1969	37-46
		Tomato harvester, with compensation to displaced workers for 50% of earnings loss		16-28
Ayer and Schuh, 1972	Brazil	Cotton	1924--1967	77-110
Hines, 1972	Peru	Maize	1954--1967	35-40 <sup>a</sup> 50-55 <sup>b</sup>
Hayami and Akino, 1977	Japan	Rice	1915--1950	25-27
Hayami and Akino, 1977	Japan	Rice	1930--1961	73-75
Hertford, Ardiia, Rocha, and Trujillo, 1977	Colombia	Rice	1957--1972	60-82
		Soybeans	1960--1971	79-96
		Wheat	1953--1973	11-12
		Cotton	1953-1972	None
Pee, 1977	Malaysia	Rubber	1932--1973	24
Peterson and Fitzliarris, 197 /	USA	Aggregate	1937--1942 1947-1952 1957--1962 1957--1972	50 51 49 34
Wennergren and Whitaker, 1977	Bolivia	Sheep	1966-1975	44
		Wheat	1966-1975	—48
Pray, 1978	Punjab (British India)	Agricultural research and extension	1906-1956	34-44
	Punjab (Pakistan)	Agricultural research and extension	1948--1963	23-37
Scobie and Posada, 1978	Bolivia	Rice	1957-1964	79-96
Pray, 1980	Bangladesh	Wheat and Rice	1961-1977	30-35

*Continued-*

Study	Country	Commodity	Time Period	Annual Internal Rate of Return(%)
<i>Regression Analysis</i>				
Tang, 1963	Japan	Aggregate	1880--1938	35
Griliches, 1964	USA	Aggregate	1949--1959	35-40
Latimer, 1964	USA	Aggregate	1949--1959	Not Significant
Peterson, 1967	USA	Poultry	1915--1960	21
Evenson, 1968	USA	Aggregate	1949--1959	47
Evenson, 1969	S. Africa	Sugar-cane	1945--1958	40
Barletta, 1970	Mexico	Crops	1943--1963	45-93
Duncan, 1972	Australia	Pasture Improvement	1948--1969	58-68
Evenson and Jha, 1973	India	Aggregate	1953--1971	40
Cline, 1975 (revised by Knutson and Tweeten, 1979)	USA	Aggregate	1939--1948	41-50°
		Research and extension	1949--1958	39-47°
			1959--1968	32-39°
			1969--1972	28-35°
Bredahl and Peterson, 1976	USA	Cash grains	1969	36 <sup>d</sup>
		Poultry	1969	37 <sup>d</sup>
		Dairy	1969	43 <sup>d</sup>
		Livestock	1969	47 <sup>d</sup>
Kalilon, Bal, Saxena, and Jha, 1977	India	Aggregate	1960--1961	63
Evenson and Flores, 1978	Asia-National	Rice	1950--1965	32-39
			1966--1975	73-78
	Asia-International	Rice	1966--1975	74-102
Flores, Evenson, and Hayami, 1978	Tropics	Rice	1966--1975	46-71
	Philippines	Rice	1966-1975	75
Nagy and Furtan, 1978	Canada	Rapeseed	1960--1975	95-110
Davis, 1979	USA	Aggregate	1949--1959	66-100
			1964--1974	37
Evenson, 1979	USA	Aggregate	1868--1926	65
		Technology-oriented	1927--1950	95
	USA	Science-oriented	1927--1950	110
	USA	Science-oriented	1948--1971	45
	Southern USA	Techno]ogy-oriented	1948--1971	130
	Northern USA	Technology-oriented	1948-1971	93
	Western USA	Technology-oriented	1948-1971	95
	USA	Farm management, research and agricultural extension	1948-1971	110

Note: This table is based on Robert E. Evenson, Paul E. Waggoner, and Vernon W. Ruttan. "Economic Benefits from Research: An Example from Agriculture". *Science*. 205. September 14, 1979. pp. 1101-1107.

Hayami, Y., and M. Akino. "Organization and Productivity of Agricultural Research Systems in Japan". In Thomas M. Arndt, Dana G. Dalrymple and Vernon W. Ruttan (eds.), *Resource Allocation and Productivity in National and International Agricultural Research*. Minneapolis:

<sup>a</sup>Returns to maize research only.

<sup>^</sup>Returns to maize research plus cultivation "package."

<sup>c</sup>Lower estimate for 13-, and higher for 16-year time lag between beginning and end of output impact.

<sup>d</sup>Lagged marginal product of 1969 research on output discounted for an estimated mean lag of 5 years for cash grains, 6 years for poultry and dairy, and 7 years for livestock.

Sources: For Table 1. The results of many of the studies reported in this table have previously been summarized in the following works.

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Boyce, James K., and Robert E. Evenson. *Agricultural Research and Extension Systems*. New York: Agricultural Development Council. 1975. p. 104.

Evenson, Robert, Paul E. Waggoner, and Vernon W. Ruttan. "Economic Benefits from Research: An Example from Agriculture". *Science*. 205. September 14, 1979. pp. 1101-1107.

Sim, Robert J. R., and Richard Gardner. *A Review of Research and Extension Evaluation in Agriculture*. Moscow, Idaho: University of Idaho, Department of Agricultural Economics Research Series 214. May 1978. pp. 4142.

The sources for individual studies are

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and mechanical technology becomes available, the returns to the acquisition of new skills in production and marketing are driven up. It becomes important not only to accept but also to be able to adapt or reject the new "packages" of practices and inputs being recommended by research and extension services. Agricultural extension services themselves must be able to advance beyond simply recommending a package of practices or delivering technological and managerial messages to farmers. They must advance from teaching practices to teaching principles!

It seems quite clear that Pakistan has not yet made the investment in the schooling of rural people to enable it to take full advantage of the potentially high-payoff technology that is becoming available. In spite of one of the world's great pieces of agricultural real estate — 35 million acres of irrigated land in the Indus basin — yields remain low by Asian standards. It is hard to avoid a conclusion that underinvestment in human capital has dampened the rate of return to investment in land and water development and to agricultural research and extension.

#### **INDUCED TECHNICAL CHANGE IN AGRICULTURE**

The high-payoff input model remains incomplete as a theory of agricultural development. Typically, education and research are public goods not traded through the marketplace. The mechanism by which resources are allocated among education, research, and other public- and private-sector economic activities was not fully incorporated into the model. It does not explain how economic conditions induce the development and adoption of an efficient set of technologies for a particular society. Nor does it attempt to specify the processes by which relationships between input and product prices induce investment in research in a direction consistent with a nation's particular resource endowment.

These limitations in the high-payoff input model led Yujiro Hayami and me to develop a model of agricultural development in which technical change is treated as an endogenous factor. This induced-innovation point of view was stimulated by the historical evidence different countries had followed alternative paths of technical change in the process of agricultural development. In the induced-innovation model, changes or differences in the economic environment influence the direction of technical change.

In discussing the Induced Innovation Model, I will find it useful, at the risk of some oversimplification, to use the term *mechanical technology* to refer to those technologies which substitute for labour and the term *biological technology* to refer to those technologies which generate increases in output per hectare.

#### Mechanical and Biological Processes in Agricultural Production

The mechanization of agricultural production cannot be treated as simply an adaptation of industrial methods of production to agriculture. The spatial nature of agricultural production results in significant differences between agriculture and industry in patterns of machine use. It imposes severe limits on the efficiency of large-scale production in agriculture.

The spatial dimension of crop production requires that the machines suitable for agricultural production must be mobile — they must move across or through materials that are immobile in contrast with the mobile material that moves through stationary machines, as in most industrial processes. Furthermore, the seasonal or spatial characteristics of agricultural production requires a series of specialized machines — for land preparation, planting, weed control and harvesting — specifically designed for sequential operations, each of which is carried out for only a few days or weeks in each season. This means that it is no more feasible for workers to specialize in one operation in mechanized agriculture than in pre-mechanized agriculture. It also means that in a "fully mechanized" agricultural system the capital-labour ratio tends to be much higher than in the industrial sector in the same country.

In agriculture, biological and chemical processes are more fundamental than mechanization or machine processes. This generalization was as true during the last century as it will be during the era of the "new biotechnology". Advances in biological and chemical technology in crop production have typically involved one or more of the following four elements: (a) land and water resource development to provide a more satisfactory environment for plant growth; (b) modification of the environment by the addition of organic and inorganic sources of plant nutrients to the soil to stimulate plant growth; (c) use of biological and

chemical means to protect plants from pests and disease; and (d) selection and design of new biologically efficient crop varieties, specifically adapted to respond to those elements in the environment that are subject to man's control. Similar processes can be observed in advances in animal agriculture.

**Induced Technical Change:  
The United States and Japan**

One implication of the discussion of mechanical and biological processes is that there are multiple paths of technical change in agriculture available to a society. The constraints imposed by an inelastic supply of land may be offset by advances in biological technology. The constraints imposed by an inelastic supply of labour may be offset by advances in mechanical technology. These alternatives are illustrated in Figure 1. The 1880-1980 land and labour productivity growth paths for Japan, Denmark, France, Germany, the United Kingdom and the United States are plotted along with the 1980 partial productivity ratios for a number of developing countries. The impression given by the several growth paths is that nature is relatively "plastic."

In economics it had generally been accepted, at least since the publication of the *Theory of Wages* by Sir John Hicks, that changes or differences in the relative prices of factors of production could influence the direction of invention or innovation. There has also been a second tradition, based on the work of Griliches and Schmookler, that has focused attention on the influence of growth in product demand on the rate of technical change. We now turn to an illustration of the role of relative factor endowments and prices in the evolution of alternative paths of technical change in agriculture in the United States and Japan.

Japan and the United States are characterized by extreme differences in relative endowments of land and labour (Table 2). In 1880, the total agricultural land area per male worker was more than sixty times as large in the United States as in Japan, and the arable land area per worker was about twenty times as large in the United States as in Japan. The differences have widened over time. By 1980, the total agricultural land area per male worker was more than one hundred times as large and the arable land area per male worker about fifty times as large in the United States as in Japan.



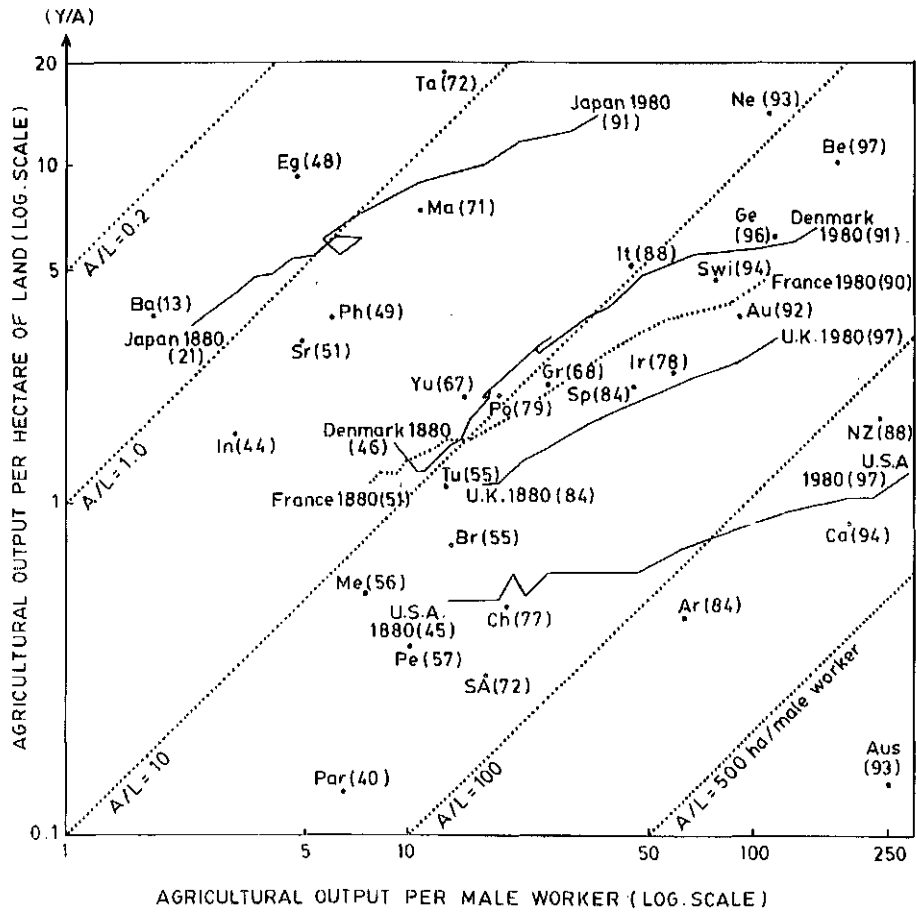


Figure 1. Historical growth paths of agricultural productivity of Denmark, France, Japan, the United Kingdom, and the United States for 1880–1980, compared with intercountry cross-section observations of selected countries in 1980.

Source: Data from Appendices A and B in Hayami and Ruttan, *Agricultural Development*, Rev. ed. (Baltimore: Johns Hopkins University Press, 1985).

Note: Values in parentheses are percentages of male workers employed in non-agriculture.

## Key to the Symbols used in Figure 1

Ar	Argentina	NZ	New Zealand
Aus	Australia	No	Norway
Au	Austria	Pak	Pakistan
Ba	Bangladesh	Par	Paraguay
Be	Belgium (& Luxemburg)	Pe	Peru
Br	Brazil	Ph	Philippines
Ca	Canada	Po	Portugal
Ch	Chile	SA	South Africa
Co	Colombia	Sp	Spain
Eg	Egypt	Sr	Sri Lanka
Fi	Finland	Su	Surinam
Ge	Germany, F.R.	Swe	Sweden
Gr	Greece	Swi	Switzerland
In	India	Sy	Syria
Ir	Ireland	Ta	Taiwan
Is	Israel	Tu	Turkey
It	Italy	UK	United Kingdom
Li	Libya	USA	United States of America
Ma	Mauritius	Ve	Venezuela
Me	Mexico	Yu	Yugoslavia
Ne	Netherlands		

Table 2

*Land-labour Endowments and Relative Prices in Agriculture:  
United States and Japan, Selected Years*

	1880	1900	1920	1940	1960	1980
<b>USA</b>						
1. Agricultural Land Area (million ha.)	327	465	458	452	440	427
2. Arable Land Area (million ha.)	93	157	194	189	185	191
3. Number of Male Farm workers (thousand)	7,959	9,880	10,221	8,487	3,973	1,792
4. Agl. Land (ha.) worker (Row 1 ÷ Row 3)	41	47	45	50	111	238
5. Arable Land (ha.) worker (Row 2 ÷ Row 3)	12	16	19	22	47	107
6. Value of Arable Land (\$/ha.)	109	106	341	178	696	3,393
7. Farm Wage Rate (\$/day)	0.90	1.00	3.30	1.60	6.60	25.31
8. No. of work-days needed by a worker to buy 1 ha. of arable land (Row 6 ÷ Row 7)	188	106	103	111	105	134
<b>Japan</b>						
9. Agricultural Land Area (thousand ha.) <sup>a</sup>	5,509	6,032	6,958	7,102	7,042	5,729
10. Arable Land Area (thousand ha)	4,749	5,200	5,998	6,122	6,071	5,461
11. Number of Male Farm Workers (thousand)	8,336	8,483	7,577	6,362	6,230	2,674
12. Agl. Land (ha.) worker (Row 9 ÷ Row 11)	0.66	0.71	0.92	1.12	1.13	2.14
13. Arable Land (ha.) worker (Row 10 ÷ Row 11)	0.57	0.61	0.79	0.96	0.97	2.04
14. Value of Arable Land (yen/ha)	343	917	3,882	4,709	1,415,000	7,642,000
15. Farm Wage Rate (yen/day)	0.22	0.31	1.39	1.90	440	5,054
16. No. of work-days needed by a worker to buy 1 ha. of arable land (Row 14 ÷ Row 15)	1,559	2,958	2,793	2,478	3,216	1,512

*Source:* Data from Appendix 'Table C-2' and C-3 in Yujiro Hayami and Vernon W. Ruttan, *Agricultural Development: An International Perspective*. Rev. ed. Baltimore: The Johns Hopkins University Press. 1985.

<sup>a</sup>Agricultural land areas in Japan for 1880-1960 are estimated by multiplying arable land areas by 1.16, the ratio of agricultural land area to arable land area in the 1960 Census of Agriculture; this conversion factor changed to 1.05 for 1980 based on the 1980 Census of Agriculture.

The relative prices of land and labour also differed sharply in the two countries. In 1880, in order to buy a hectare of arable land (compare Row 8 and Row 16 in Table 2), it would have been necessary for a Japanese hired farm-worker to work eight times as many days as a U.S. farm-worker. In the United States, the price of labour rose relative to the price of land, particularly between 1880 and 1920. In Japan, the price of land rose sharply relative to the price of labour, particularly between 1880 and 1900. By 1960, a Japanese farm-worker would have had to work thirty times as many days as a U.S. farm-worker in order to buy one hectare of arable land. This gap was reduced after 1960, partly because of the extremely rapid increases in wage rates in Japan during the two decades of "miraculous" economic growth. In the United States, land prices rose sharply in the post-war period primarily because of the rising demand for land for non-agricultural use and the anticipation of continued inflation. Yet, in 1980 a Japanese farm-worker still would have had to work eleven times as many days as a U.S. worker to buy one hectare of land.

In spite of these substantial differences in land area per worker and in the relative prices of land and labour, both the United States and Japan experienced relatively rapid rates of growth in production and productivity in agriculture (Tables 3 and 4). Overall agricultural growth performance for the entire 100-year period was very similar in the two countries. In both countries, total agricultural output increased at an annual compound rate of 1.6 percent while total inputs (aggregate of conventional inputs) increased at a rate of 0.7 percent. Total factor productivity (total output divided by total input) increased at an annual rate of 0.9 percent in both countries. Meanwhile, labour productivity, measured by agricultural output per male worker, increased at the rate of 3.1 percent per year in the United States and of 2.7 percent in Japan. It is remarkable that the overall growth rates in output and productivity were so similar despite the extremely different factor proportions which characterize the two countries.

Although there is a resemblance in the overall rates of growth in production and productivity, the time sequences of the relatively fast-growing phases and the relatively stagnant phases differ between the two countries. In the United States, agricultural output grew rapidly up to 1900; then the growth rate decelerated. From the 1900s to the 1930s,

Table 1  
*Average Annual Rates of Change (percentage per year) in Output,  
 Inputs, and Productivity in U.S. Agriculture, 1870-1982*

Item	1870- 1900	1900- 1925	1925- 1950	1950- 1965	1965- 1982
Farm Output	2.9	0.9	1.6	1.7	2.1
Total Inputs	1.9	1.1	0.2	-0.4	0.2
Total Productivity	1.0	-0.2	1.3	2.2	1.8
Labour Inputs*	1.6	0.5	-1.7	-4.8	-3.4
Labour Productivity	1.3	0.4	3.3	6.6	5.8
Land Inputs <sup>1</sup>	3.1	0.8	0.1	-0.9	0.0
Land Productivity	-0.2	0.0	1.4	2.6	1.8

*Sources:* U.S. Department of Agriculture, *Economic Indicators of the Farm Sector: Production and Efficiency Statistics, 1980* (Washington, D.C.: USDA, Economic Research Service, January 1982, and subsequent issues); U.S. Department of Agriculture, *Changes in Farm Production and Efficiency* (Washington, D.C.: 1979); and D. D. Durost and G. T. Bartonj *Changing Sources of Farm Output* (Washington, D.C.: USDA Production Research Report, Report No. 36, February 1960). Data are three-year averages centred on the year shown for 1925, 1950, and 1965.

<sup>a</sup>Number of workers, 1870-1910; worker-hour basis, 1910-1971.

<sup>b</sup>Cropland use for crops, including crop failures and cultivated summer fallow.

there was little gain in total productivity. This stagnation phase was succeeded by a dramatic rise in production and productivity in the 1940s and 1950s. Japan experienced rapid increases in agricultural production and productivity from 1880 to the 1910s, then entered into a stagnation phase which lasted until the mid-1930s. Another rapid expansion phase commenced during the period of recovery from the devastation of World War II. Roughly speaking, the United States experienced a stagnation phase two decades earlier than Japan and also shifted to the second development phase two decades earlier.

The effect of relative prices on the development and choice of technology is illustrated with remarkable clarity for biological technology in Figure 2. In that figure, the U.S. and Japanese data on the relationship between fertilizer input per hectare of arable land and the fertilizer/land price ratio are plotted for the period from 1880 to 1980.

Table 1

*Average Annual Change in Total Output, Inputs, and Productivity  
in Japanese Agriculture, 1880-1980.*

Item	1880- 1920	1920- 1935	1935- 1955	1955- 1965	1965- 1980
Farm Output	<b>1.8</b>	0.9	0.6	3.5	1.2
Total Inputs	0.5	0.5	1.2	<b>1.3</b>	0.7
Total Productivity	1.3	0.4	-0.6	2.2	0.5
Labour Inputs	-0.3	-0.2	0.6	-2.5	-3.7
Labour Productivity	2.1	1.1	0.0	6.0	4.9
Land Inputs	0.6	0.1	-0.1	0.1	-0.6
Land Productivity	1.2	0.8	0.7	3.4	<b>1.8</b>

*Sources:* Data from Saburo Yamada and Yujiro Hayami, "Agricultural Growth in Japan, 1880-1970". In *Agricultural Growth in Japan, Taiwan, Korea and the Philippines*, Yujiro Hayami, Vernon W. Ruttan, and Herman Southworth, (eds.) (Honolulu: University Press of Hawaii, 1979), pp. 33-58; Saburo Yamada, "The Secular Trends in Input-Output Relations of Agricultural Production in Japan, 1878-1978" A paper presented at the Conference of Agricultural Development in China, Japan, and Korea, Academia Sinica, Taipei, December 17-20, 1980; Saburo Yamada, *Country Study on Agricultural Productivity Measurement and Analysis - Japan* (Tokyo: University of Tokyo Institute of Oriental Culture, October 1984, Mirneo).

In both 1880 and 1980, U.S. farmers were using less fertilizer than Japanese farmers. However, despite enormous differences in both physical and institutional resources, the relationship between these variables has been almost identical in the two countries. As the price of fertilizer decline relative to other factors, scientists in both countries responded by developing crop varieties that were more responsive to the lower prices of fertilizer. American scientists, however, always lagged behind the Japanese by several decades because the lower prices of land relative to the price of fertilizer in the United States resulted in a lower priority being placed on yield-increasing technology.

The effect of changes in the relative prices of mechanical power and labour in the United States and Japan for the 1880—1980 period is illustrated in Figure 3. In both 1880 and 1980, U.S. farmers used more mechanical power than Japanese farmers. But the relationship between the power/labour price ratio and the use of power per worker is again,

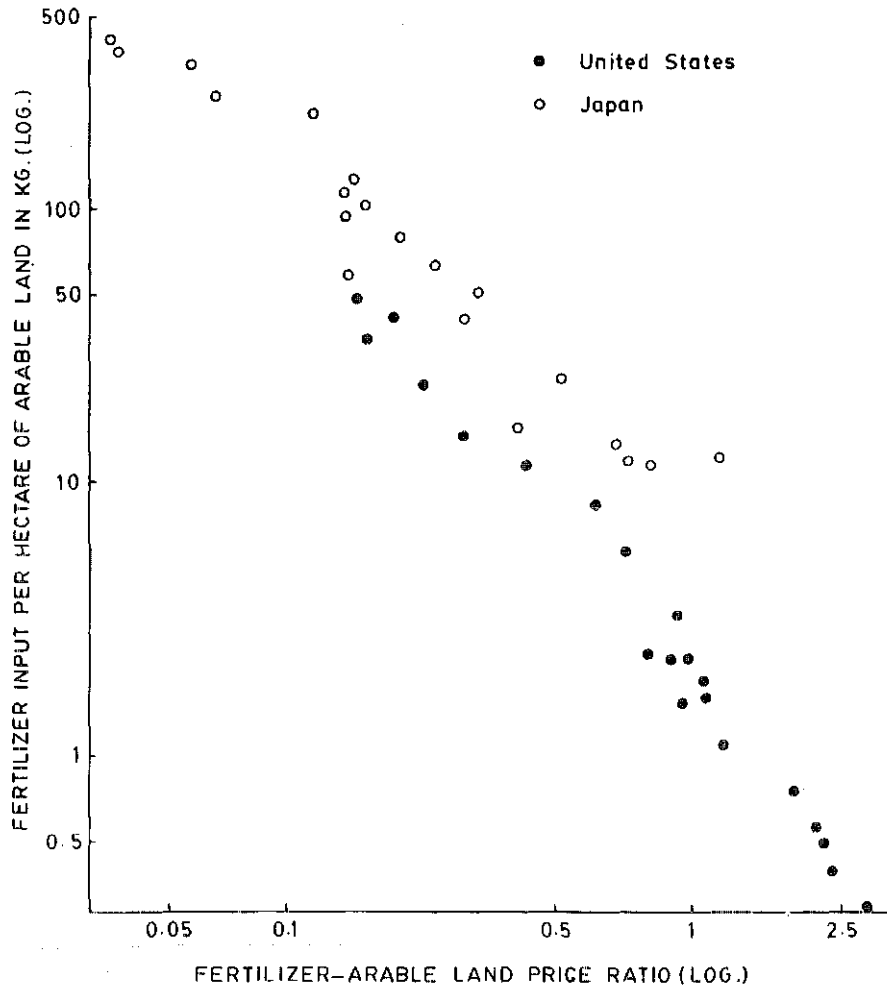


Figure 2. Relation between fertilizer input per hectare of arable land and fertilizer/arable land price ratio (= hectares of arable land which can be purchased by one ton of  $N + P_2O_5 + K_2O$  contained in commercial fertilizers), the United States and Japan, quinquennial observations for 1880–1980.

Source: Data from Appendix C in Hayami and Ruttan, *Agricultural Development*, Rev. ed. (Baltimore: Johns Hopkins University Press, 1985).

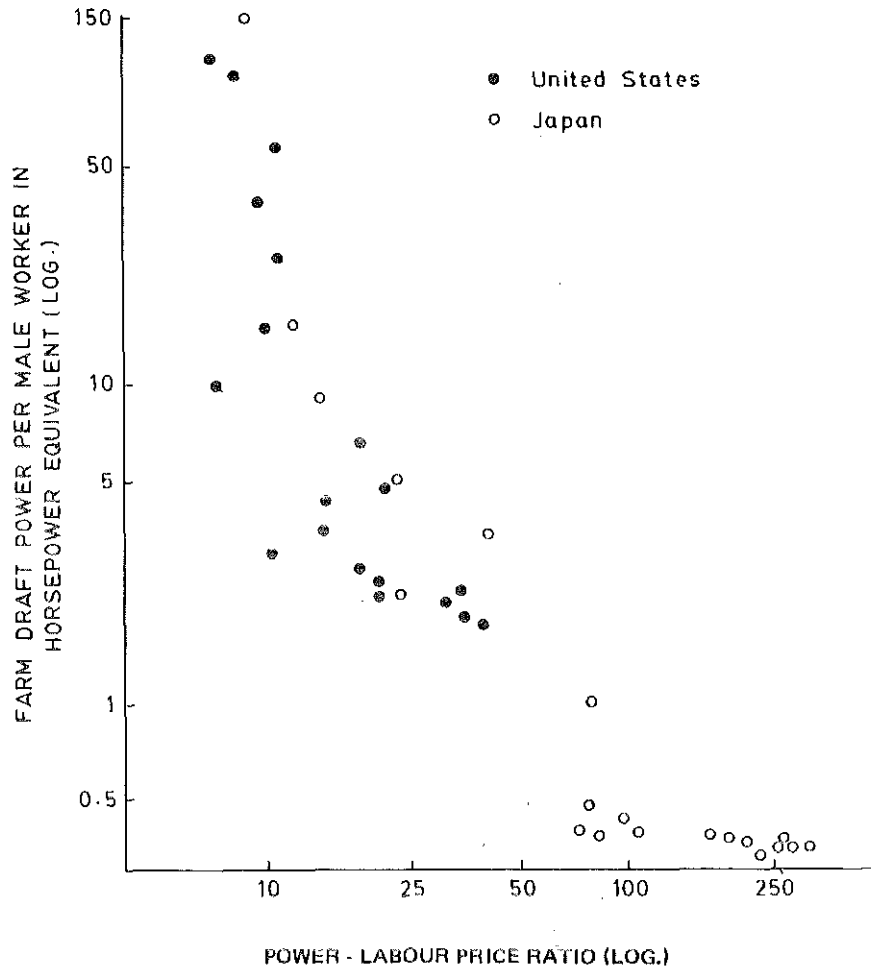


Figure 3. Relation between farm draft power per male worker and power-labour price ratio (= hectares of work days which can be purchased by one horsepower of tractor or draft animal), the United States and Japan, quinquennial observations for 1880–1980.

Source: Data from Appendix C, Hayami and Ruttan, *Agricultural Development*, Rev. ed. (Baltimore: Johns Hopkins University Press, 1985).

Note: Number of male workers = U3 and J3, Power = U7 + U8 and J7 + J8, Land price = U19 and J19, Power price = average retail price of tractor per horsepower extrapolated by U21 from the 1976–80 average of \$216 for the United States, and extrapolated by J21 from the average of 65,170 yen for Japan.



almost identical in the two countries. But, because labour was always less expensive in Japan, the Japanese suppliers of mechanical technology always lagged behind the U.S. suppliers by several decades. These same relationships that hold for Japan and the United States have now been demonstrated for the 1880—1960 period for a number of European countries in the book by Hans P. Binswanger and Vernon W. Ruttan, *Induced Innovation: Technology, Institutions and Development*.

The effect of a rise in the price of fertilizer relative to the price of land or of the price of labour relative to the price of machinery has been to induce advances in biological and mechanical technology. The effect of the introduction of lower cost and more productive biological and mechanical technology has been to induce farmers to substitute fertilizer for land and mechanical power for labour. These responses to differences in resource endowments among countries and to changes in resource endowments over time by agricultural research institutions, by the farm supply industries, and by farmers, has been remarkably similar in spite of differences in cultures and traditions.

The results of our comparative analyses can be summarized as follows. Agricultural growth in the United States and Japan during the 1880—1980 period can best be understood when viewed as a dynamic factor-substitution process. Factors have been substituted for each other along a metaproduction function in response to long-run trends in relative factor prices. Each point on the metaproduction surface is characterized by a technology which can be described in terms of specific sources of power, types of machinery, crop varieties, and animal breeds. Movements along this metaproduction surface involve technical changes. These technical changes have been induced to a significant extent by the long-term trends in relative factor prices.

#### PERSPECTIVE

In the closing decades of the twentieth century, we are approaching the end of the most remarkable transitions in the history of agriculture.

Prior to the beginning of this century, almost all increases in agricultural production occurred as a result of increases in the area cultivated. The major exceptions were in *Western Europe*, where

livestock-based conservation systems of farming had developed, and in *East Asia*, where wet rice cultivation systems had developed.

But, by the end of this century there will be few significant areas where agricultural production can be expanded by simply adding more land to production. Enlargement of agricultural output will have to be secured almost entirely through more intensive cultivation of the areas already being used for agricultural production. Increases in food and fibre production will depend, in a large measure, on continuous advances in agricultural technology.

The task before us is clear. It is imperative, *over the next several decades, that we complete the establishment of agricultural research capacity for each commodity of economic significance in each agro-climatic region of the world.*

A developing country which fails to evolve a capacity for technical and institutional innovation in agriculture, consistent with its resource and cultural endowments, suffers two major constraints on its attempts to develop a productive agriculture. It is unable to take advantage of advances in biological and chemical technologies suited to labour-intensive agricultural systems. And the mechanical technology it does import from more developed countries will only be productive under conditions of large-scale agricultural organization. It will contribute to the emergence of a "bimodal" rather than a "unimodal" organization structure.

During the last two decades, a number of developing countries have begun to establish the institutional capacity to generate technical changes adapted to national and regional resource-endowments. More recently, these emerging national systems have been buttressed by a new system of international crop and animal research institutes. These new institutes have become both important sources of new knowledge and technology and increasingly effective communication links among the developing national research systems.

The lag in shifting from a natural-resource-based to a science-based system of agriculture continues to be a source of national differences in land and labour productivity. Lags in the development and application

of knowledge are also important sources of regional productivity differences within countries. In countries such as Mexico and Pakistan, differential rates of technical change have been an important source of the widening disparities in the rate of growth of total agricultural output, in labour and land productivity, and in incomes and wage rates among regions.

Productivity differences in agriculture are increasingly a function of investments in scientific and industrial capacity and in the education of rural people rather than of natural-resource endowments. The effects of education on productivity are particularly important during periods in which a nation's agricultural research system begins to introduce new technology. In an agricultural system characterized by static technology, there are few gains to be realized from education in rural areas. Rural people who have lived for generations with essentially the same resources and the same technology have learned from long experience what their efforts can get out of the resources available to them. Children acquire from their parents the skills that are worth while. Formal schooling has little economic value in agricultural production.

As soon as new technical opportunities become available, this situation changes. Technical change requires the acquisition of new husbandry skills; acquisition from nontraditional sources of additional resources such as new seeds, new chemicals, and new equipment; and development of new skills in dealing both with natural resources and with the input and product market institutions that link agriculture with the non-agricultural sector.

The processes by which new knowledge can be applied to alter the rate and direction of technical change in agriculture are, however, substantially greater than our knowledge of the processes by which resources are brought to bear on the process of institutional innovation and transfer. Yet the need for viable institutions capable of supporting more rapid agricultural growth and rural development is even more compelling today than it was a decade ago. I will attempt to deal with the process of institutional innovation and change in my second lecture.

## DISCUSSION

*Dr M. A. Hussein Mullick:* After listening to your lecture, I have the feeling that it is technology which has been moving agriculture. But there is another aspect which you have completely neglected and not even touched upon and that is the social aspect. There are quite a large number of factors which are as important as technology and sometimes the introduction of successful technology is hindered or stopped because of the non-availability of those social environments, and that is something which, I felt, was missing in your lecture.

Secondly, you did mention the three crops that the Germans introduced but you perhaps forgot to mention one very important aspect that was developed in Germany and elsewhere in Europe and that was that the cattle which you said were necessary to produce farm manure were not always a positive factor for the farmer. He got liberated from this burden later on through the advent of chemical fertilizers in the market, and my understanding of German agriculture is that this very use of the chemical fertilizer served to force the farmer to produce more as marketable surplus, and I think this was not less than a revolution.

The third point arises from a rather disappointing note in your very interesting lecture and that is based on your last remark which in fact was an anticlimax of your whole exercise. I do agree from the logical point of view and maybe from the chronological emphasis point of view that before mechanization there is a need for a certain environment and some know-how. I think Friedrich List may have never been known if he had not advocated the use of a particular technology for the Germans so that they could one day compete with their cousins, the English people. I think we, too, in Pakistan have recently set up a Steel Mill knowing too well that it is going to be a big loss for the economy but knowing also that in the longer run, the Steel Mill is likely to be very beneficial, if you have the minuses in the short run, I am sure that if you also count the pluses in the longer run even on the use of the technology, your analysis will take a different shape. As a consequence, if we falter in the short run, I am certain that technology is sure to build bridges for future prosperity in the long run.

*Prof. Vernon W. Ruttan:* I appreciate your comments. Let me respond to each of them. You are correct in pointing out that technology is not the only factor. In my lecture tomorrow I am going to talk about institutional innovation. However, it does seem to me quite clear that the absence of technical progress constrains what could be achieved by institutional change. Unless one has a rice variety that will respond to higher levels of fertilizer, the institutions that can deliver fertilizer to farmers will not be very productive. But if one does have the rice that can respond and one does not have the institutions, one will not get the production either. So I think we have to give very serious consideration to the issue of institutional innovation. Your point about cattle is also important. Another point I would like to make is that these models which I have laid out are not stages. Growth within the framework of each of the models is available to some extent at each time in history. Animals manures, by themselves, set a very low limit on the rate of increase in fertility. But it would be wasteful for a country that is producing animal manures not to use the animal manures along with the chemical manures. But without chemical fertilizers we would be very badly off.

I also appreciate your reference to Friedrich List. In my book I have a rather long discussion on some of his ideas. You may remember that prior to the 1850s and 1860s the Germans looked to England as the "school of agriculture". After the development of chemistry, the English had to start looking at Germany as the school of agriculture. I am not a *laissez-faire* economist. I have emphasized, in the case of agricultural research, that "socialization" of agricultural research is essential. The issue of what industries should be encouraged at a particular time is, I think, partly a question of appropriate timing.

A principle I do insist on is that it does not pay to save things that are not worth very much. It does pay to save scarce resources. And if a country is going to generate the growth dividends that it takes to further growth, then it must focus its scientific effort and the investment of its limited capital resources on those areas that generate the most growth. Each country should apply the principle in terms of its understanding of its own resources and capacities.

*Dr Ghulam Rasul:* Let me start by paying my compliments to Prof. Ruttan on a highly illuminating lecture. I have one small question

relating to your high-payoff model where you have emphasized the actual availability of inputs at reasonable prices to the farmers and then the development of technology which suits the factor endowments or resource endowments. You have dealt with the input side of agriculture only and to my mind the villain of the piece is the price of the agricultural output where agriculture has to face two types of handicaps. One is in the international market where the agricultural products, especially the foodgrains, have to face competition from industrialized countries. I mean, agriculture in the developing countries has to face competition from the industrialized high-technology agriculture and then high-technology subsidized agriculture. Then, secondly, within the national economies, agriculture is faced with the very serious problem of pricing. Typically the industrial sector enjoys a highly protected market as compared with what agriculture enjoys in the pricing of its outputs with sometimes 200 300 percent protection for industrial products. I wonder if Prof. Ruttan has carried out any exercises regarding the relative prices of the outputs of the agricultural and non-agricultural sectors in the economies of these countries and then seen what happened to agriculture?

*Prof. Vernon W. Ruttan:* There are several very important questions involved in the points you made. Let me state a generalization and then go on to some of your more specific points. One of the things that we have to be very clear about is that a subsidy to any sector is a tax on all other sectors. That means that we must be very clear about what we want to achieve with a subsidy. Another thing that is very important in the generation of an appropriate agricultural technology is that we don't give our scientists and our engineers the wrong signals about what is expensive and what is cheap, if the problem was simply a choice of technology, of buying a turn-key plant, the mistake could be taken care of in a few years by rust. But if we bias the price signals, the effect will be to bias the kind of technology that agricultural scientists and engineers invent, if we impose a high tariff on fertilizer, as in Argentina in the 1950s and 1960s, plant breeders do not proceed to invent fertilizer-responsive crop varieties. The effect, in Argentina, was to set back progress in the agricultural sector by two decades. It is generally not feasible to acquire new biological technology simply by going out and buying it from abroad. It must be invested in the agro-climatic region where it is to be used.

*Dr Ghulam Rasul:* The pricing mechanism, to my mind, plays an important role in the diversion of resources. Resources don't get transferred to agriculture for the simple reason that the pricing mechanism doesn't favour it here.

*Prof. Vernon W. Ruttan:* There is a policy issue, if the prices are distorted — if you put your hand on the thermostat and won't let it work — the furnace will not perform effectively. In Argentina, nitrogen fertilizer was priced at double the world price because they had a small obsolete fertilizer plant that was owned by a family whose members were high-ranking people in the military. Argentinian scientists did not develop fertilizer-responsive maize varieties because they did not believe that their farmers could afford to buy fertilizer. Policy-makers should think very carefully about those indirect effects of price and trade policies. The longer-run indirect effects can be very powerful in both the agricultural and the industrial sectors. You may want to bias some prices to direct resources into favoured areas of economic activity, or you may want to bias certain other areas to slow down activity, but you should know why you are doing it.

*Dr M. Fahim Khan:* A very basic question still remains unclear to my mind. Take the case of Japan and the USA. In one of the charts you presented, the growth path is vertical in agriculture in Japan but the growth path is horizontal in the case of the USA. We can explain the vertical growth path by saying that a labour-augmenting technological change has been taking place in Japan and a land-augmenting technological change has been taking place in the USA. We know from the theory of comparative advantage that a country specializes with respect to the abundant resource and if the countries are sufficiently open then the invisible hand of the market will induce the countries to develop these types of desired technological changes. The question then remains why the invisible hand of the market has not been inducing the developing countries to get the desired technological changes as they have been successful in the cases of Japan and the USA.

*Prof. Vernon W. Ruttan:* Let me emphasize that I do not put much faith in the invisible hand. It is not the invisible hand that built the Japanese agriculture research and extension services. It was the visible hand of public policy. But the visible hand was asking itself what was important.

What was important in Japan in 1880 was not the same thing that was important in the United States or UK in 1880. Japan was able to send the British and American advisers home because they were not provided by an aid agency. Japan was paying! And when they decided that they were not getting appropriate technical advice from the Americans and the British, they turned to the Germans.

I want to again emphasize that the institutions that determine prices were invented by man. Markets do not exist naturally — they have to be invented. It may be strategic, if markets are operating effectively, to act as if the invisible hand were operating. Tomorrow in my lecture on institutional innovation I will want to come back to this issue.

*Prof. Mian M. Nazeer:* First of all, I would like to thank Prof. Rurtan for serving us such rich food for thought. It seems that there is such a great deal that one can learn from the history of agricultural change and development about the relationship that exists between agriculture and technological development. Obviously, if agriculture is to develop, there must be technological change. But then comes the question of applying this technological change or technical change to agriculture. In that, when we come to your model, we hear about the role of the public sector. What is the important role which agriculture has to play? Of course, public sector is not the only one, or exclusively the one, that could play the role, but it has an important role to play. Now, of course, with that comes the difficulty of history. Has the public sector also been developing to be able to play that role? Unless it has simultaneously developed to take over at that point of history the role which devolves upon it, that part will remain unfulfilled and that is our history and our experience. That part of the public sector that can play the role is itself a very scarce resource despite the fact that it is a very large sector that we have. That is my first point.

The second point that I have is that there is need, in our case, specifically speaking from the experience of Pakistan, for a kind of technology to sustain the result of technological change once the technology has been applied to agriculture. Today you apply technology, and even if you can educate the farmer in accepting and applying it, tomorrow if the green pills turn yellow, then the farmer slides back to his original beliefs and his original practices, if something fails, he thinks



that there was something wrong with what was given to him. This has to be followed up till success follows. Success and a particular technology becomes a sort of habit and a practice with the farmer. I do not know if these points would be acceptable to you.

*Prof. Vernon W, Ruttan:* I very much appreciate your first point. The point you are making is that in the early stages of development the public sector has limited capacity. The capacity of the public sector is itself a scarce resource. If we dissipate the limited professional capacity or the limited scientific capacity of the public sector to perform functions that could be readily performed by the private sector, we are wasting a very important resource. That is why, while I emphasized the need to socialize agricultural research, I did not advocate the socialization of the entire economy.

*Mr. Jamil Nishter\*:* My main comment is about: the substance of Prof. Ruttan's lecture. He has emphasized the equation between technology, delivery capacity and the receiving capacity. Now, in the delivering capacity the issue is, of course, of research or of adaptation and of experimentation, then of the delivery of that through the institutional system which makes those things and makes them available to the farmer. That is, of course, very correct and in that, I think, there has been a lot of progress in the last 30 years and the systems are becoming better in terms of delivery capacity. It is the second part of the equation, the receiving capacity or what may be called the absorption capacity, which worries me and I think that is an area where Prof. Ruttan, who is very active in this field, and his colleagues and the people in our country should do more research, because just to say that farmers need schooling to adopt this technology is not saying very much. For instance, in a country like ours, the present illiteracy rate is 72 percent. There is no hope whatsoever of having a good literacy rate till about the year 2020 or so. Does that mean, therefore, that we will postpone agricultural technology till then? We just cannot do that. There has been a tremendous development of the audio-visual communication in the last 10-20 years plus what Prof. Ruttan has very correctly referred to as the inherent efficiency of the peasant. Now the peasant may not, of course, be able to understand the plays of Shakespeare but he would be able to know what particular type of seed he should use, late variety

\*Mr. Jamil Nishter died of heart failure on June 9, 1986.

or early variety, if that information is properly presented to him. I think the failure of the education system in the developing countries is so major that it cannot be made a prerequisite for agricultural development. If it is made so, then that will doom this sector for the next 50 years to underdevelopment. Therefore, for the agriculture sector, we have to find a route to education in the broader sense of that word which bypasses the traditional literacy and educational systems, and on that I have a comment. The comment actually relates to the issue of hardware and software and this issue of rusting tractors lying on the lane. My own experience has been actually that there is a rather superficial understanding of the issue. What is normally propagated by the policy-makers in countries like ours and in the academic circles is that you should be very good with software before you are going to get any hardware. The system either withholds hardware from outside or withholds hardware from inside and makes an assumption that you will have to become very expert and only then are you going to get the hardware. Now, the reality is that the farmer is not going to learn the use of hardware until he actually has it. For hardware there are two stages. The first stage of hardware will necessarily involve waste. No farmer is actually going to learn about tractors without having a tractor. I was absolutely shocked when I sent one of my officers to visit agricultural training institutes. There are five institutes of training of field assistants in the country. None of the institutes has a single tractor. There is a two-year course for field assistants but none of them has even a single tractor. I see actually no alternative but a certain amount of deliberate waste in the early stages. In the early stages, the import of hardware or the availability of hardware, whether it is in the form of seed or chemical fertilizer or tractor or implements, etc., will definitely be badly used, but that is the only way the recipients will learn how to use it and then the next stage will come. In our country, actually this concept is already clear. For instance, the World Bank in its various loans had always been putting a lot of emphasis on the creation of agricultural institutions for training of tractor drivers and tractor mechanics and the like. They have been saying this for the last 20 years. Not a single institute has come into being; but, in the mean time, some very smart tractor drivers and some very smart tractor mechanics have come into being in Faisalabad and Sargodha. If you go outside Faisalabad you can see workshops where there are young boys who are quite smart and know how to repair tractors. We are entering a second stage where the first stage of waste has

already given education to a certain class. Of course, this is not usual in all regions of the country. But, the comment that I am making is that in the case of technical change in a developing country, the absorption capacity of the farmer is extremely important and that absorption capacity cannot wait for a liberal education system to strike roots first. Somehow or the other, the absorption capacity has to be created through an actual operational type of effort in which in the first stage we must accept waste and inefficiency only as an educational element so that in the second stage we are able to use hardware properly.

*Prof. Vernon W. Ruttan:* Thanks for the two, excellent comments. We now have a good deal of evidence on the value of formal education. We also know that informal education such as agricultural education can represent a partial substitute for formal education. Low levels of schooling and literacy do not preclude progress but they do impose a substantial burden. I do not know of any country that has been able to extract anywhere near the full productivity inherent in its agricultural technology without achieving a fairly high level of literacy and numeracy in its rural population.

The difference between mechanical technology and biological technology is extremely important. Mechanical technology in agriculture is not simply an extension of industrial technology. In industry, the machine stands still and the materials move, In crop production, the material stands still and the machines have to move. That means that in a fully mechanized agricultural system the capital-labour ratio is going to be higher than in a fully mechanized industrial system.

Another thing that intrigues me is the point you made about the way mechanics and blacksmiths and farmers have learned so rapidly about mechanical technology. We experienced it in the United States; one can see it in India; and one can see it here in Pakistan. But we do not often see farmers inventing new crop varieties. The difference is that in mechanical technology the scientific frontier and the technical frontier are quite close. Mechanical knowledge becomes pervasive very easily. In biological technology, there is a much larger gap between the scientific frontier and the technical frontier. There may come a time when biological knowledge will be so widely diffused that people will invent their own crop varieties. But we are a long way from that point at present.

There are very different motivations, very different economic forces, operating on the development and diffusion of mechanical and biological technologies. My friends in economics often do not seem to understand that you can have a modern biological technology without needing a modern mechanical technology. Or you can have a modern mechanical technology without needing a modern biological technology. The question is: What is the appropriate mix between the two? I find even in the countries where labour is most abundant — where wages are extremely low — that men are not very efficient at pumping water. There is an appropriate sequence in the development and use of mechanical technology. Stationary machines come first. Machines that move come second.

*Mr Manzoor Ahmad:* I have been personally greatly impressed by the highly illuminating lecture by Prof. Ruttan. I have just two comments to make. I think in all the models that he has mentioned both with the traditional approach and with government intervention or public sector intervention, the need for rural infrastructure does not seem to have been covered. I think this is very important for ensuring that the inputs reach the farmers and, more particularly, the outputs find an outlet to the market. And, of course, when I say infrastructure, I include the electricity network also. I think the need for this is paramount in a country which has small farmers and where equity considerations dictate its creation.

The second comment that I would like to make is that this urban industrial impact model is very interesting. Of course, it requires to be accelerated and the need for linking production with marketing is very important. It is, in fact, a much more accelerating process than even technology change and we have found it in the sugar-cane area particularly. When we linked marketing with production and processing with production, there was some kind of a revolution created. We are thinking of seeing to it that there are more and more instances created in the country on this basis, in order to accelerate the process of production. Farmers are prepared to produce, but if they can get a market link-up, this is more important.

*Prof. Vernon W. Ruttan:* I find myself in very close agreement with both of your comments. We need to think about both the physical infrastructure and the institutional infrastructure needed to sustain

agricultural development. We often tend to underestimate the need for development of market institutions during the process of rapid development. Consider, for example, a society in which the marketable surplus is 20 percent, moving in a period of two decades to a situation where output has doubled and the marketable surplus rises to 40 percent of production. This implies an increase of four times in the product that must move through market channels.

*Dr A.R. Kemal:* Prof. Ruttan, you said that you are not one of the great believers in the market economy or the price mechanism or the invisible hand and you would like to see a much greater role for the public sector. If we refer back to your first chart, it raises a very important policy issue in the public sector. What you put on the graph was that there was mechanical technology and biological technology and Japan developed biological technology because land was scarce and the USA went for the mechanical type of technology because labour was much cheaper there. If we look at the factor endowment of Pakistan, it seems that we are much closer to those days when Japan developed biological technology. Land is a big constraint and labour is still cheap. However, in Pakistan what we are doing at present is that, together with the biological technology, we are giving much greater attention to developing, or at least disseminating, mechanical technology. Now, if a policy decision has to be taken, would it really mean that we should be making a shift, for the time being at least, from mechanical technology towards biological technology?

*Prof. Vernon W. Ruttan:* When you say that I don't place any emphasis on the market you are pushing me further than I would like to go. The point I was trying to make is that in the process of development there are certain activities for which the public sector accepts responsibility if they are going to be done at all. And there are other activities that should be left to the private sector - which are much more efficiently handled by the private sector than by the public sector. I don't want you to push me into saying that the public sector in Pakistan needs to be even bigger than it is. On careful study, I would probably come to the opposite view.

I am going to let those of you in Pakistan who wish to do so argue about the relative priority of biological and mechanical technology. But

I have no doubt that you must increase the investment needed to advance biological technology. You have already invested more than almost any other country in the world in developing the irrigation system needed for an intensive agriculture system.

You must also invest in the development of the biological technology needed to make what is clearly some of the best agricultural real estate in the world more productive. The Indus Basin is capable of producing more intensively than almost any other area in the world. If you fail to make use of that abundant resource, you would be wasting one of your great assets. I don't know enough about the factor proportions and factor endowments of Pakistan to advise you on the appropriate mix of mechanical and biological technology, but I do stress the importance of doing the analysis that will permit you to make suitable decisions about the appropriate path of technical change.

*Dr Faiz Mohammad:* Prof. Ruttan, I found your lecture both interesting and inspiring, but still I feel it would be unfair to you as well as to us if I do not point out where I have my reservations about the central message of your lecture. In the developing countries, there has been a trend of jumping to adopt any and every new suggestion coming from outside for developing agriculture. We know that when high-payoff input got currency, we accepted it as the solution to the problem of agriculture. So, when I look at your lecture and the emphasis on technical change, I would like to check with you if this emphasis on technical change represents a model for agricultural development. I am asking this because when you talk of a model for agricultural development, we must take into consideration not only how the innovations which have been well accepted as essential for development, will take place but also how they are actually to be adopted, because both these things depend on the overall framework within which a particular sector and a particular economy is placed. We know that our rural sector is not suffering from just low productivity; that there are other aspects also which may have restricted not only the technological change but also the overall development in agriculture. This is my first point.

The second point is that when you give the example of Japan and Korea, it also reminds me of Arthur Lewis's emphasis on the role of

agriculture in bringing about industrial development. To him, the only way of bringing about a new international economic order is going through the agriculture route. To learn from an example, I think we must first try to look at the essential elements which make that example take place. Now, on that account, when we look at our situation, I do not see that we have tried to follow all the essential elements. Primarily, the point which I want to make is that, in those examples, they first determined the position of agriculture and of their economy and then they mustered the resources accordingly. In other words, they were fully aware of the nature and the requirements of the role of agriculture in their economies. Unfortunately, in our case what we see is a half-hearted policy. There are many shifts taking place from time to time, and, as a result, we do not see the same kind of revolution taking place as in Japan and Korea. So what we need is to first correctly identify the place of agriculture and then muster the resources accordingly both for technological change and for agricultural development.

*Prof. Vernon W. Ruttan:* I am very much in agreement with your comment. The message I would like to come out of my presentation is that there is a unique path of technological change that is consistent with the resource and cultural endowments of each country. The Japanese path is just the Japanese path! The U.S. path is just the United States path! And neither of those paths may be appropriate for any other country. If a country is going to escape the low-productivity trap and do it efficiently without wasting resources that have other uses, it needs to look at its own situation. But it cannot have access to the world's biological technology unless it makes the appropriate investment in agricultural research capacity. It can't really have access to the world's mechanical technology that is adapted to its own environment unless it has the capacity to adapt, embody and produce that technology, A country the size of Pakistan is quite fortunate because it can potentially make either kind or both kinds of investment, if appropriate. A smaller country such as Nepal or Rwanda is almost forced into the position of borrowing most of its technology whether it is appropriate or not.

*Mr Israr-ul-Haq:* You have built up your theory of agricultural development on the following premises:

1. Growth in agriculture productivity and production is now possible only through intensive agriculture as the land frontier cannot be extended.
2. It is only by advanced technology that we can escape the trap of the Ricardian stagnation.
3. Growth in agriculture induced by technical change will simultaneously meet the equity requirements.

These assumptions are open to question in view of the following findings of the relevant studies made by different authorities:

1. The report on the *Limits to Growth* prepared by the Club of Rome indicates that about 2.5 billion hectares of land is still available for being brought under cultivation, i.e. only half of the available land in the world is being cultivated at present.
2. Higher technological changes are responsible for the pollution of the environment and the fast depletion of the resources and these constitute a serious limit to further growth.
3. Studies carried out by ILO show that the Green Revolution in Asia, induced by seed and fertilizer technology, has not only perpetuated poverty but has also in some cases accentuated it.

Please comment.

*Prof. Vernon W. Ruttan:* My major criticism of the *Limits to Growth* study is that it is analysis without data. It employed a very simple model. Technological change of the kind we are talking about in agriculture hardly played any role in the model.

There is more land that can be brought into more intensive cultivation. The great plains of Brazil and Venezuela, the llanos and campos cerrado, are examples. These lands are now being used only for very extensive grazing. They are not, however, suitable for pioneer cultivation of the kind we discussed in the traditional resource exploitation model until very severe soil problems, such as aluminium toxicity, have been solved. Most of the remaining areas of the world that might be used



more intensively have rather severe resource problems that prevent them from being farmed more intensively. Very substantial scientific and technical advances will be required to make such lands available for more intensive cultivation.

A lot of nonsense has been written about the Green Revolution. The Green Revolution was produced by people like plant breeders, people who wore white coats and rubber boots, and did not spend much time philosophizing about economic development. Prior to the Green Revolution, the economists and sociologists thought the development business belonged to them. Then the agronomists and plant breeders came along with some dramatic advances that the press began referring to as the Green Revolution. Much of the early criticism reflects interdisciplinary aggression. It was based on very casual empiricism. Now, a decade later, our data and analysis indicate that the biological technology has been neutral with respect to scale. Small farmers have adopted the biological technology more rapidly than large farmers. That is exactly what we should expect from an understanding of the implication of relative factor endowments. The new biological technology permits more intensive cultivation. It facilitates the use of more labour per hectare. The small farmer has more labour per hectare. A recent set of studies conducted in 28 villages throughout Asia found only one of those areas where the large farmers adopted the new seed-fertilizer technology faster than small farmers.

Dr Ghaffar Chaudhry in Pakistan has done some very interesting work that indicates that many of the early impressions about unfavourable distribution effects were simply not consistent with facts. We have heard many assertions that small farmers could not afford high levels of inputs. But the factor share of output going to fertilizer has rarely exceeded 15 percent. The value of the increase in output was often several times the increase in fertilizer cost. It is hard to avoid the conclusion that many of the early evaluations were very strongly ideologically motivated. And in most of them the empirical work was excessively casual.

Those ILO studies were very seriously flawed. First of all, they covered a period when the Green Revolution didn't really have any significant effect. Studies conducted using data from the 1960s and 1970s could not possibly capture the effect of the Green Revolution,

Another reason that they were flawed is that they attempted to look only at the technology-poverty relationship. They did not look at the relationships among population growth, technology, and poverty. Any serious attempt to understand what is happening to income distribution in Asian villages must consider the effects of population growth as well as technical change.

*Dr M. Ghaffar Chaudhry:* The lecture by Prof. Ruttan has been very interesting but I would like to seek clarification on one point. Pakistan, in recent years, has been following in agriculture a policy of input prices which have at least grown at 3 times the rate of output price increases. This is the history of the last four years. In the future as well, I think, there will be only limited possibilities of increases in output prices. But the government aims at increasing input prices further in order to eliminate subsidies. My question to Prof. Ruttan is: Does Pakistan have any prospects of rapid agriculture development in the future, given the situation that I have cited?

*Prof. Vernon W. Ruttan:* The implication of the framework that I have used suggests that if one wants to give Pakistani scientists, engineers, and farmers the right signals, both input prices and output prices should be priced as near the border prices as possible. The question of whether Pakistan can be competitive in foodgrain production over the long run is partly a question of the other opportunities for the use of these very productive physical resources in the irrigated areas of Pakistan. It may be that the opportunity to produce higher-valued commodities than foodgrains will emerge. In California, we can probably produce higher yields of wheat than in any other parts of the United States. But we don't use very much Californian land to produce wheat because it can produce other things that are even more valuable. The purpose of technical changes is to reduce the real costs of production. When one looks back over the period of 1880 to 1980, the real price of wheat declined by about 50 percent. Wheat is available to consumers today on the world scale at about half the price that prevailed in 1880. And the world is a lot better off for that. Pakistan should continually ask itself whether it can improve the rate of productivity growth in wheat production rapidly enough for wheat to remain an economic crop or whether there are more productive uses for the Indus Basin land and water.

*Lecture II*

**INSTITUTIONAL CHANGE AND  
AGRICULTURAL DEVELOPMENT**

*Lecture II*

**INSTITUTIONAL CHANGE AND  
AGRICULTURAL DEVELOPMENT**

Professor Naqvi, Dr Sarfraz Qureshi, and distinguished guests:

Over the last several decades, economists have made major contributions to our understanding of the impact of the knowledge of natural science on technical change and the impact of technical change on economic growth. We have also significantly advanced our understanding of the sources of demand for and supply of technical change.

In a work published in the early 1970s, Yujiro Hayami and I extended the theory of induced technical change and tested it against the history of agricultural development in the United States and Japan. It is now generally accepted that the theory of induced technical change provides very substantial insights into the process of agricultural development for a wide range of the developed and developing countries. And economic historians are increasingly drawing on the theory of induced technical change in attempting to interpret differential patterns of productivity growth among countries and over time. The central elements of the theory of induced technical change were discussed yesterday in my first lecture.

The demonstration that technical change can be treated as largely endogenous to the development process does not imply that the progress of either agricultural or industrial technology can be left to an 'invisible

hand' that drives technology along an 'efficient' path determined by relative resource endowments. The capacity to advance knowledge in science and technology is itself a product of institutional innovation. Whitehead has insisted that "the great invention of the nineteenth century was the invention of the method of invention."

In the case of agriculture, for example, in both Japan and the United States, much of the technical change that has led to growth of output per hectare has been produced by public-sector institutions. These institutions — State (or prefectural) and federal (or national) agricultural experiment stations — obtain their resources in the political market place and allocate their resources through bureaucratic mechanisms. The success of the theory of induced technical change gives rise, therefore, to the need for a more careful consideration of the sources of institutional innovation and design.

In this paper, I elaborate a theory of institutional innovation in which shifts in the demand for institutional change are induced by changes in relative resource endowments and by technical change. I also consider the impact of advances in the knowledge of social sciences and of cultural endowments on the supply of institutional change. After examining the forces that act to shift the demand for and supply of institutional change, I present the elements of a more general model of institutional change. The point of view on the role of institutional change in the process of economic development presented in this paper is much more positive than the views that were held by the American institutional school or in the recent literature on social choice and collective action.

### **WHAT IS INSTITUTIONAL INNOVATION?**

Institutions are the rules of a society or of organizations that facilitate co-ordination among people by helping them to form expectations which each person can reasonably hold in dealing with others. They reflect the conventions that have evolved in different societies regarding the behaviour of individuals and groups relative to their own behaviour and the behaviour of others. In the area of economic relations, they have a crucial role in establishing expectations about the rights to use resources in economic activities and about the partitioning of the income streams

resulting from economic activity — 'institutions provide *assurance* respecting the actions of others, and give order and stability to expectations in the complex and uncertain world of economic relations'.

In order to perform the essential role of forming reasonable expectations in dealings among people, institutions must be stable for an extended time period. But institutions, like technology, must also change if development is to occur. Anticipation of the latent gains to be realized by overcoming the disequilibria resulting from changes in factor endowments, product demand, and technical change represents a powerful source of demand for institutional innovation. Institutions that have been efficient in generating growth in the past may, over time, become obstacles to further economic development. The growing disequilibria in resource allocation due to institutional constraints on the opportunities for economic growth create an environment in which it becomes profitable for political entrepreneurs or leaders to organize collective action to bring about institutional change.

This viewpoint on the sources of demand for institutional change is similar, in some respects, to the traditional Marxian view. Marx considered technological change as a primary source of institutional change. "At a certain stage of their development, the material forces of production in society come in conflict with the existing relations of production, or — what is but a legal expression for the same thing — with the property relations within which they had been at work before. From forms of development of the forces of production these relations turn into their fetters. Then comes the period of social revolution. With the change of the economic foundation the entire immense super-structure is more or less rapidly transformed."

The view that Professor Hayami and I have used in our work is somewhat more complex. We consider that changes in factor endowments and product demand are equally important sources of institutional change. Nor is institutional change limited to the dramatic or revolutionary changes of the type anticipated by Marx. Basic institutions such as property rights and markets are more typically altered through the cumulation of 'secondary' or incremental institutional changes such as modifications in contractual relations or shifts in the boundaries between market and non-market activities.

There is a supply as well as a demand dimension in institutional change. Collective action leading to changes in the supply of institutional innovations may be generated by tension among interest groups. Clearly, the process is much more complex than the simple class conflict between those who derive their income from the ownership of property and those who derive their income from labour. The supply of institutional innovations is strongly influenced by the cost of achieving social consensus (or of suppressing opposition). The cost of institutional change is dependent on the distribution of political resources. And it also depends critically on cultural tradition and ideology.

Advances in knowledge in the social sciences (and in related professions such as law, administration, planning, and social service) can reduce the cost of institutional change much as advances in the natural sciences reduce the cost of technical change. Education, both general and technical, that facilitates a better understanding among people of their common interests can also reduce the cost of institutional innovation.

Our insistence that important advances in the understanding of the processes of institutional innovation and diffusion can be achieved by treating institutional change as endogenous to the economic system represents a clear departure from the tradition of modern analytical economics. This does not mean that analytical economics must be abandoned. On the contrary, it is suggested that the scope of modern analytical economics should be expanded by treating institutional change as endogenous.

#### **DEMAND FOR INSTITUTIONAL INNOVATION: MARKET INSTITUTIONS**

In some cases, the demand for institutional innovation can be satisfied by the development of new forms of property rights, by more efficient market institutions, or even by evolutionary changes arising out of direct contracting by individuals at the level of the community or the firm. In other cases, where externalities are involved, substantial political resources may have to be brought to bear to organize non-market institutions in order to provide for the supply of public goods. It may be useful to illustrate, from the agricultural history of England, Thailand and the

Philippines, how changes in factor endowments, technical change, and growth in product demand have induced changes in property rights and contractual arrangements in order to promote a more efficient resource allocation.

The agricultural revolution that occurred in England between the fifteenth and nineteenth centuries involved a substantial increase in the productivity of land and labour. It was accompanied by the enclosure of open fields and the replacement of small peasant cultivators, who held their land from manorial lords, by a system in which large farmers used hired labour to farm the land they leased from the landlords. The First Enclosure Movement, in the fifteenth and sixteenth centuries, resulted in the conversion of open arable fields and commons to private pasture in areas suitable for grazing. It was induced in substantial part by expansion in the export demand for wool. The Second Enclosure Movement in the eighteenth century involved conversion of communally managed arable land into privately operated units.

There has been a continuing debate among students of English agricultural history whether the higher rent that landowners received after enclosure was (a) because enclosed farming was more efficient than open-field farming, or (b) because enclosures redistributed income from farmers to landowners. It is now agreed, however, that it was largely induced by the growing disequilibrium between the fixed institutional rent that landlords received under copyhold tenures (with lifetime contracts) and the higher economic rents expected from adoption of new technology which became more profitable as a consequence of higher grain prices and lower wages. When the land was enclosed, there was a redistribution of income from farmers to landowners and the disequilibrium was reduced or eliminated.

Thailand's example, based on an exceedingly useful study by David Feeny of the political economy of Thai agricultural development, draws on more recent economic history. In Thailand, in the middle of the last century, land was abundant and labour was scarce. Property rights in land were poorly defined and were based primarily on occupancy. But property rights in people were defined in almost baroque complexity. There were several gradations in slavery, ranging from war



captives to debt shares. And there was also a complex system of servile obligations on the part of the peasantry to the nobility and the king. Debt slavery provided a form of collateral for credit transactions in the absence of well-defined property rights in land. One could sell one's child, one's wife, or one's self into debt slavery with, under certain conditions, a right of redemption.

A shift from "property rights in man to property rights in land" began when Thailand opened itself up to international trade, under British and French pressure. The trend was reinforced following the construction of the Suez Canal and the reduction in shipping rates to Europe. The sharp increase in the demand for rice, associated with cheaper access to European markets, made land suitable for rice production more valuable. The land available for rice production, which had been abundant, became more scarce. Investment in land development for rice production became profitable. The response was a major transformation of property rights. Traditional rights in human property (corvee and slavery) were replaced by more precise private property rights in land (fee-simple titles). These changes were encouraged by the king and his advisers because it reduced the status of the Thai nobility from that of warlords to landlords. And it was accepted by the nobility because it substituted increasingly valuable land rights for less valuable feudal privilege.

In Japan, at the beginning of the feudal Tokugawa period (1603—1867), peasants' rights to cropland had been limited to the rights to till the soil with the obligation to pay a feudal land tax in kind. As the population grew, commercialization progressed and irrigation and technology were developed to make intensive farming more profitable. Some peasants divided their holdings into smaller units and leased them out to ex-servants or extended family members. Some accumulated land through mortgaging arrangements that made other peasants *de facto* tenants. As a result of the accumulation of illegal leasing and mortgaging practices, peasants' property rights in land approximated those of a fee-simple title by the end of the Tokugawa period. These rights were readily converted to the modern private-property system in the succeeding Meiji period.

Research conducted by Yujiro Hayami and Masao Kikuchi in the Philippines during the late 1970s has enabled us to examine a contemporary example of the interrelated effects of changes in resource endowments and technical change on the demand for institutional change in land tenure and labour relations. The case is particularly interesting because the institutional innovations occurred as a result of private contracting among individuals. The study is unique in that it is based on a rigorous analysis of micro-economic data in a village over a period of about 20 years.

#### Changes in Technology and Resource Endowments

Between 1956 and 1976, rice production per hectare in the study village rose dramatically, from 2.5 to 6.7 metric tons per hectare per year. This was due to two technical innovations. In 1958, the national irrigation system was extended to the village. This permitted double cropping to replace single-cropping, thereby substantially increasing the annual production per hectare of rice land. The second major technical change was the introduction in the late 1960s of the modern high-yielding rice varieties. The diffusion of modern varieties was accompanied by an increased use of fertilizer and pesticides and by the adoption of improved cultural practices such as straight-row planting and intensive weeding.

Population growth in the village was rapid. Between 1966 and 1976, the number of households rose from 66 to 109 and the population rose from 383 to 464, while cultivated area remained virtually constant. The number of landless labourer households increased from 20 to 54. In 1976, half of the households in the village had no land to cultivate, not even land for rent. The average farm size declined from 2.3 to 2.0 hectares.

The land is farmed primarily by tenants. In 1976, only 1.7 hectares of the 108 hectares of cropland in the village were owned by village residents. In both 1956 and 1966, 70 percent of the land was farmed under share tenure arrangements. In 1963, a new agricultural land reform code was passed which was designed to break the political power of the traditional landed elite and to provide greater incentives to peasant producers of basic food crops. A major feature of the new legislation was an arrangement that permitted tenants to initiate a shift from share

tenure to leasehold, with rent under the leasehold set at 25 percent of the average yield for the previous three years. Implementation of the code between the mid-1960s and the mid-1970s resulted in a decline in the percentage of land farmed under share tenure to 30 percent.

### **Institutional Innovation**

The shift from share tenure to lease tenure was not, however, the only change in tenure relationships that occurred between 1966 and 1976. There was a sharp increase in the number of plots farmed under subtenancy arrangements. The number increased from one in 1956, to sixteen in 1976. Subtenancy is illegal under the land reform code. The subtenancy arrangements are usually made without the formal consent of the landowner. All cases of subtenancy were on land farmed under a leasehold arrangement. The most common subtenancy arrangement was a fifty fifty sharing of costs and output.

The incentive for the emergence of the subtenancy institution came from the fact that the rent paid to landlords under the leasehold arrangement was below the equilibrium rent — the level which would reflect both the higher yields of rice obtained with the new technology and the lower wage rates implied by the increase in population pressure against the land.

To test this hypothesis, market prices were used to compute the value of the unpaid factor inputs (family labour and capital) for different tenure arrangements during the 1976 wet season. The results indicate that the share-to-land was the lowest and the operators' surplus was the highest for the land under leasehold tenancy. In contrast, the share-to-land was the highest and no surplus was left for the operator who cultivated the land under the subtenancy arrangement (Table 5). Indeed, the share-to-land when the land was farmed under subtenancy was very close to the sum of the share-to-land plus the operators' surplus under the other tenure arrangement. A substantial portion of the economic rent was captured by the leasehold tenants in the form of operators' surplus. On the land farmed under a subtenancy arrangement, the rent was shared between the leaseholder and the landlord.

A second institutional change, induced by higher yields and the increase in population pressure, has been the emergence of a new pattern



of employer-labour relationship between farm operators and landless workers. According to the traditional system called *hunusan*, labourers who participated in harvesting and threshing received a one-sixth share of the harvest. By 1976, most of the farmers (83 percent) adopted a system called *gamma*, in which participation in the harvesting operation was limited to those workers who had performed the weeding operation without receiving wages.

The emergence of the *gamma* system can be interpreted as an institutional innovation designed to reduce the wage rate for harvesting to a level equal to the marginal productivity of labour. In the 1950s, when the rice yield per hectare was low and labour was less abundant, the one-sixth share may have approximated an equilibrium wage level. With the higher yields and the more abundant supply of labour, the one-sixth share became larger than the marginal product of labour in the harvesting operation.

To test the hypothesis that the *gamma* system was adopted rapidly primarily because it represented an institutional innovation that permitted farm operators to equate the harvesters' shares of output to the marginal productivity of labour, imputed wage costs were compared with the actual harvesters' share (Table 6). The results indicate that a substantial gap existed between the imputed wage for the harvesters' labour alone and the actual harvesters' shares. This gap was eliminated if the imputed wages for the harvesting and weeding labour were added.

Those results are consistent with the hypothesis that the changes in institutional arrangements governing the use of production factors were induced when disequilibria between the marginal returns and the marginal costs of factor inputs occurred as a result of changes in factor endowments and technical change. Institutional change, therefore, was directed toward the establishment of a new equilibrium in factor markets.

### **Efficiency and Equity**

It is important to recognize that subtenancy and *gamma* contracts were the institutional innovations to facilitate more efficient resource allocations through voluntary agreements by assigning more complete

Table 6  
*Comparison between the Imputed Value of Harvesters' Share  
 and the Imputed Cost of Gamma Labour*

	Based on Employers' Data	Based on Employees' Data
No. of Working Days of <i>Gamma</i> Labour (days/ha.) <sup>a</sup>		
Weeding	20.9	18.3
Harvesting/Threshing	33.6	33.6
Imputed Cost of <i>Gamma</i> Labour (P/ha.) <sup>b</sup>		
Weeding	167.2	146.4
Harvesting/Threshing	369.6	369.6
<b>(1) Total</b>	<b>536.8</b>	<b>516.0</b>
Actual Share of Harvesters:		
In kind (kg/ha.) <sup>c</sup>	504.0	549.0
<b>(2) Imputed Value (P/ha.)<sup>d</sup></b>	<b>504.0</b>	<b>549.0</b>
<b>(2) - (1)</b>	<b>-32.8</b>	<b>33.0</b>

*Source:* Yujiro Hayami and Masao Kikuchi, *Asian Village Economy at the Crossroads: An Economic Approach to Institutional Change* Tokyo: University of Tokyo Press, 1981; and Minneapolis: University of Minnesota Press, 1982, p. 121.

<sup>a</sup>Includes labour of family members who worked as *Gamma* labourers.

<sup>b</sup>Imputation using market wage rates (daily wage = P8.0 for weeding, P11.0 for harvesting).

<sup>c</sup>One-sixth of output per hectare.

<sup>d</sup>Imputation using market prices (1 kg = P1).

private property rights. The land reform laws gave tenants strong protection of their tenancy rights with the result that a part of land property rights, which is the right to continue tilling the soil at a rent lower than the marginal product of land, was assigned to tenant operators. But the laws prohibited tenants from renting their land to someone else who might utilize it more efficiently, when they become elderly or found more profitable off-farm employment, for example. Subtenancy was developed to reduce such inefficiency due to the institutional rigidity in the land rental market based on the land reform programmes. Likewise, the *gamma* system was developed to counteract the institutional rigidity in the labour market based on the traditional custom in the rural community in the form of a fixed harvester's share.

It might appear that these institutional innovations increased efficiency at the expense of equity. But, if the subtenancy system had not been developed, the route would have been closed for some of the landless labourers to become farm operators and use their entrepreneurial abilities more profitably. If the implicit wage rate for harvesting work had been raised in the absence of the *gamma* contract, it might have encouraged mechanization in threshing and thereby reduced employment and labour earnings. It must be recognized that the institutional innovations that resulted in more efficient markets as a result of the assignment of more complete private property rights do not necessarily impair equity, as is often argued by Marxist and populist critiques of private market institutions.

In the case reviewed here, the induced innovation process leading toward the establishment of equilibrium in land and labour markets occurred very rapidly in spite of the fact that many of the transactions-between landlords, tenants, and labourers — were less than fully monetized. Informal contractual arrangements or agreements were utilized. The subleasing and the *gamma* labour contract evolved without the mobilization of substantial political activity or bureaucratic effort. Indeed, the subleasing arrangement evolved in spite of legal prohibition! Where substantial political and bureaucratic resources must be mobilized to bring about technical or institutional change, the changes occur much more slowly, as in the cases of the English enclosure movements and the Thai and Japanese property rights cases referred to at the beginning of this section.

The Philippine village study reviewed in this section was specifically designed to facilitate the analysis of the interrelationships between changes in resource endowments, technical change and institutional change. It would be extremely valuable to have additional studies specifically designed for this purpose. It would, for example, be particularly useful to examine the interrelationships among the expansion of gravity irrigation systems, the public programmes to reduce waterlogging and salinity, the development of private tubewells, the introduction of high-yielding varieties of wheat and rice, the mechanization of land preparation and harvesting, and the rapid growth of rural population and changes in market and non-market institutions in the Pakistani Punjab.

#### DEMAND FOR INSTITUTIONAL INNOVATION: NON-MARKET INSTITUTIONS

The examples of institutional change advanced in the previous section, such as the Enclosure in England and the evolution of private property rights in land in Japan and Thailand, have contributed to the development of a more efficient market system. Institutional changes of this type are profitable for society only if the costs involved in the assignment and protection of rights are smaller than the gains from a better resource allocation. If those costs are very high, it may be necessary to design non market institutions in order to achieve a more efficient resource allocation.

For example, in Japan, although the system of private property rights was developed on cropland during the pre modern period, communal ownership at the village level permitted open access to large areas of wild and forest land which were utilized for the collection of firewood, leaves, and wild grasses to fertilize rice fields. However, over time, more detailed common property rules were stipulated for the use of communal land in order to prevent resource exhaustion.

Detailed stipulations of the time and place of utilization of communal land as well as rules for mobilizing village labour to maintain communal property (such as applying fire to regenerate pasture) were often enforced with religious taboos and rituals. Those communal village institutions remained viable because it was much more costly to demarcate



and partition wild and forest land than cropland among individuals and to enforce an exclusive use. Any villager's use of communal land involves externality. For example, his collection of firewood reduced the availability of the firewood for other villagers, if property rights are not assigned, there may be only a limited incentive for resource conservation. This is not a serious problem if the resource that is subject to open access is abundant relative to population. However, as population pressure begins to rise, a common understanding regarding appropriate use, reinforced by social sanctions, may act to limit excessive exploitation. But, as population growth continues to press against limited land resources and the market value of the resource product rises, it becomes necessary to impose more formal regulations regarding the access of individual villagers to communal land.

Group action to supply public goods, such as the maintenance of communal land, may work effectively if the size of the group involved is small, as in the case of a village community. However, if a large number of people are involved in the use of a public good, as in the case of marine fisheries, it is more difficult to regulate their resource use or to prevent free riders by means of voluntary agreements. Action by a higher authority with coercive power, such as government, may be required to limit free riding.

The 'socialization' of agricultural research is common not only in socialist economies but also in market economies. This can be explained by the failure of the market in allocating resources efficiently for the supply of public goods for a large, unidentifiable clientele group. New information or knowledge resulting from research is typically endowed with the attributes of a public good characterized by *non-rivalness* or jointness in supply and utilization, and *non-excludability* or external economies. The first attribute implies that the good is equally available to all. The second implies that it is impossible for private producers to appropriate through market pricing the full social benefits arising directly from the production (and consumption) of the good — it is difficult to exclude from the utilization of the good those who do not pay for it. A socially optimal level of supply of such a good cannot be expected if its supply is left to private firms. However, present institutional arrangements are such that much information resulting from basic research is

non-excludable. This is the major reason why it has been necessary to establish non-profit institutions to advance basic scientific knowledge.

A unique aspect of agricultural research, particularly that directed to advancing biological technology, is that many of the products of research—even in the applied area — are characterized by non-excludability. Protection by patent laws is either unavailable or inadequate. The nature of agricultural production to be conducted would make it difficult to restrict information about new technology or practices. Furthermore, even the largest farms are relatively small units and would not be able to capture more than a small share of the gains from inventive activity. Private research activities in agriculture have been directed primarily toward developing mechanical technology for which patent protection is established.

Another important attribute of the research production function is that it has a stochastic form. Research, by nature, is characterized by risk and uncertainty. Success in a research project is like hitting a 'successful oil well.' Any number of dry holes may be bored before the successful one is found. Richard Nelson has pointed out that this stochastic nature of the research production function, which is especially strong in the case of basic research, contributes to the failure of the market in attaining optimum resource allocation over time.

The very large variance of the profit probability distribution from a basic-research project will tend to cause a risk-avoiding firm, without the economic resources to spread the risk by running a number of basic-research projects at once, to value a basic-research project at significantly less than its expected profitability and hence . . . at less than its social value.

The public-good attributes of the agricultural research product together with the stochastic nature of the research production function make public support of agricultural research socially desirable. It does not necessarily follow, however, that agricultural research should be conducted in governmental institutions financed by tax revenue. If the benefit consists primarily of producers' surplus, agricultural research may be left to the co-operative activities of agricultural producers (i.e. to the

activities of such institutions as agricultural commodity organizations and co-operatives). In the United States, organized producers are funding an increasing share of agricultural research by means of a tax or a cess on production.

The willingness of organized producers to share the costs of research appears to be related to the elasticity of demand in domestic and international markets for a specific commodity. Research on a number of tropical export crops grown under plantation conditions such as sugar, bananas, and rubber is also often supported in this manner. The emergence of new institutional arrangements such as plant variety registration, which provides patent-like protection for new crop varieties, also acts to shift the optimum allocation of agricultural research resources in favour of the private sector.

However, most agricultural commodities are produced by a number of small producers. Under these conditions, voluntary co-operation to support research would be very costly to organize. Furthermore, most agricultural commodities, except those intended for export, are characterized by low price-elasticity of demand. As a result, a major share of the social benefit produced by research tends to be transmitted to consumers through lower market-prices. In such a situation, the cost of agricultural research should be borne by the general public.

If agricultural research were left entirely to the private sector, the result would be a serious bias in the allocation of research resources. Resources would flow primarily to those areas of mechanical and chemical technology that are adequately protected by patents and to those areas of biological technology where the results can be protected by trade secrets (such as the inbred lines used in the production of hybrid corn seed). Other areas, such as research on open-pollinateci seed varieties, biological control of insects and pathogens, and improvements in farming practices and management, would be neglected. The socialization of agricultural research or the predominance of public institutions in agricultural research, especially in the biological sciences, can be considered a major institutional innovation designed to offset what would otherwise represent a serious distortion in the allocation of research resources.

### THE SUPPLY OF INSTITUTIONAL INNOVATION

We have identified the disequilibria in economic relationships associated with economic growth, such as technical change leading to the generation of new income streams and changes in relative factor endowments, as important sources of demand for institutional change. But the sources of supply of institutional innovation are less well understood. The factors that reduce the cost of institutional innovation have not been widely studied by economists or by other social scientists.

In the Philippine village case, changes in tenure and labour market institutions were supplied, in response to the changes in demand generated by changing factor endowments and new income streams, through the individual and joint decisions of owner-cultivators, tenants and labourers. But even at this level it was necessary for gains to the innovators to be large enough to offset the risk of ignoring the land reform prohibitions against subleasing and the social costs involved in changing traditional harvest-sharing arrangements. While mobilization of substantial political resources was not required to introduce and extend the new land and labour market institutions, the distribution of political resources within the village did influence the initiation and diffusion of the institutional innovations.

The supply of major institutional innovations, however, necessarily involves the mobilization of substantial political resources. It is useful to think in terms of a supply schedule of institutional innovation that is determined by the marginal cost schedule facing political entrepreneurs as they attempt to design new institutions and resolve the conflicts among various interest groups (or suppression of opposition when necessary). This implies that institutional innovations will be supplied if the expected return from the innovation that accrues to the politician entrepreneurs exceeds the marginal cost of mobilizing the resources necessary to introduce the innovation. To the extent that the private return to the political entrepreneurs is different from the social return, the institutional innovation will not be supplied at a socially optimum level.

The supply of institutional innovation depends critically on the power structure or balance among interest groups in a society. If the

power balance is such that the political entrepreneurs' efforts to introduce an institutional innovation with a high rate of social return are adequately rewarded by greater prestige and stronger political support, a socially desirable institutional innovation may occur. However, if the institutional innovation is expected to result in a loss to a dominant political block, the innovation may not be forthcoming even if it is expected to produce a large net gain to society as a whole. And socially undesirable institutional innovations may occur if the returns to the entrepreneur or the interest group exceed the gains to society.

The failure of many developing countries to institutionalize the agricultural research capacity needed to take advantage of the large gains from relatively modest investments in technical change may be due, in part, to the divergence between social returns and the private returns to political entrepreneurs. In the mid-1920s, for example, agricultural development in Argentina appeared to be proceeding along a path roughly comparable to that of the United States. Mechanization of crop production lagged slightly behind that in the United States. Grain yields per hectare averaged slightly higher than in the United States. In contrast with those in the United States, however, output and yields in Argentina remained relatively stagnant between the mid-1920s and the mid-1970s. It was not until the late 1970s that Argentina began to realize significant gains in agricultural productivity. Part of this lag in Argentine agricultural development was due to the disruption of export markets in the 1930s and 1940s. Students of Argentine development have pointed to the political dominance of the landed aristocracy, to the rising tensions between urban and rural interests, and to inappropriate domestic policies toward agriculture. The Argentine case would seem to represent a situation in which the bias in the distribution of political and economic resources imposed exceptionally costly delays in the institutional innovations needed to take advantage of the relatively inexpensive sources of growth that technical change in agriculture could have made available.

Cultural endowments, including religion and ideology, exert a strong influence on the supply of institutional innovation. They make some forms of institutional change less costly to establish and impose severe costs on others. For example, the traditional moral obligation in

the Japanese village community to co-operate in joint communal infrastructure maintenance has made it less costly to implement rural development programmes there than in societies where such traditions do not prevail. These activities had their origin in the feudal organization of rural communities in the pre-Meiji period. But practices such as maintenance of village and agricultural roads and of irrigation and drainage ditches through joint activities in which all families contribute labour were still practised in well over half of the hamlets in Japan as recently as the 1970s.

Japanese scholars who are concerned about the modernization of social institutions tend to emphasize the decline in the practices of such traditional forms of co-operation — they emphasize that the traditional forms of co-operation are practised in *only* about half of the rural hamlets in Japan. Scholars who are concerned about the continuity of traditional cultural values stress the continued viability of traditional institutions. They point out that only about half of the hamlets still practise traditional forms of co-operation. In my view, such traditional patterns of co-operation have represented an important cultural resource on which to erect modern forms of co-operative marketing and joint farming activities. Similar cultural resources are not available in South Asian villages where, for example, the caste structure inhibits co-operation and encourages occupational specialization.

Likewise, the aspirations associated with the adoption of new ideological commitments may reduce the cost to political entrepreneurs of mobilizing collective action for institutional change. For example, in the United States, the Jeffersonian concept of agrarian democracy provided ideological support for the series of land ordinances culminating in the Homestead Act of 1862, which established the legal framework designed to encourage an owner-operator system of agriculture in the American West. Strong nationalist sentiment in Meiji Japan, reflected in slogans such as 'A Wealthy Nation and Strong Army' (Fukoku Kyohei), helped to mobilize the resources needed for the establishment of vocational schools and agricultural and industrial experiment stations. In China, communist ideology, reinforced by the lessons learned during the guerrilla period in Yen-an, inspired the mobilization of communal resources to build irrigation systems and other forms of physical infrastructure and social overhead capital. Thus, ideology can be a critical

resource for political entrepreneurs and an important factor affecting the supply of institutional innovations.

Advances in social sciences that improve knowledge relevant to the design of institutional innovations which are capable of generating new income streams or which reduce the cost of conflict resolution also act to shift the supply of institutional change to the right. Throughout history, improvements in institutional performance have occurred primarily through the slow accumulation of successful precedents or as by-products of expertise and experience. Institutional change was generated through the process of trial and error much in the same manner that technical change was generated prior to the invention of the research university, the agricultural experiment station, or the industrial research laboratory. With the institutionalization of research in the social sciences and related professions, the process of institutional innovation has begun to proceed much more efficiently. It is becoming increasingly possible to substitute social science knowledge and analytical skill for the more expensive process of learning by trial and error.

If this view is correct, it suggests that a major source of demand for social science knowledge is derived from the demand for institutional innovation. But, how responsive is the supply of social science knowledge to the demand for institutional change arising out of social conflict or economic growth? Is the supply of social science knowledge sufficiently elastic to reduce the cost of institutional change? Or, is society typically faced with a situation in which the demand for institutional innovation shifts against a relatively inelastic supply curve? The most pervasive view among historians of economic thought is that the supply of social science knowledge is relatively inelastic.

My own view is somewhat more optimistic. In the field of development, the research that led to advances in our understanding of the production and consumption behaviour of rural households in less developed countries represents an important example of the contribution of advances in social science knowledge to the design of more efficient institutions. In a number of countries, this research has led to the abandonment of the policies that viewed peasant households as unresponsive to economic incentives. And it has led to the design of policies and

institutions to make more productive technologies available to peasant producers and to the design of more efficient price policies for factors and products. Similarly, the diffusion of education designed to raise the intellectual level of the general public and to facilitate better understanding of the private and social costs of institutional change may reduce the cost to political entrepreneurs of introducing socially desirable institutions and raise the cost of biasing institutional change in a manner that is costly to society.

How might we test this view that the demand for institutional change, or improvements in institutional performance, is a primary source of demand for social science knowledge? One method is to draw on comparative international experience. Which societies tend to draw most extensively on social science knowledge and which societies draw least on social science knowledge in policy design and reform? It seems clear that societies in which the design of social institution is strongly determined by ideology or religion exhibit a very weak demand for social science knowledge. The USSR, for example, tends to draw primarily on that narrow range of economics most closely related to engineering — input/output analysis, mathematical programming, and sector modelling. In China, much of the capacity in economics is devoted to rationalizing the implications of shifts in economic ideology. Relatively little capacity is devoted to institutional design.

It also seems clear that the demand for social science knowledge is strongest in those societies and in those historical periods in which the burdens of ideology, religion and tradition impose relatively weak constraints on institutional design. And, within any society, it seems apparent that the demand for social science knowledge is strongest when that society is attempting to confront the problems of the present rather than when it is attempting to recapture romantic memories of the past or pursuing Utopian visions of the future.

#### **TOWARD A MORE COMPLETE MODEL OF INSTITUTIONAL CHANGE**

This review of the state of our knowledge with respect to the forces and processes of institutional innovation leaves one with two general



viewpoints. The first is that it is possible to use the tools of modern analytical economics to advance our understanding of the process of institutional change. The second is that the state of our knowledge remains highly unsatisfactory. But how do we continue the tentative advances that have been made? Instead of attempting to provide a direct response to this question, let me map out where we have been and where I think we are in this quest.

I illustrate, in Figure 4, the elements of a model that maps the general-equilibrium relationships among resource endowments, cultural endowments, technology and institutions. The model goes beyond the conventional general-equilibrium model in which resource endowments, technology, institutions, and culture (conventionally designated as tastes) are taken as given and are ignored in the analysis.

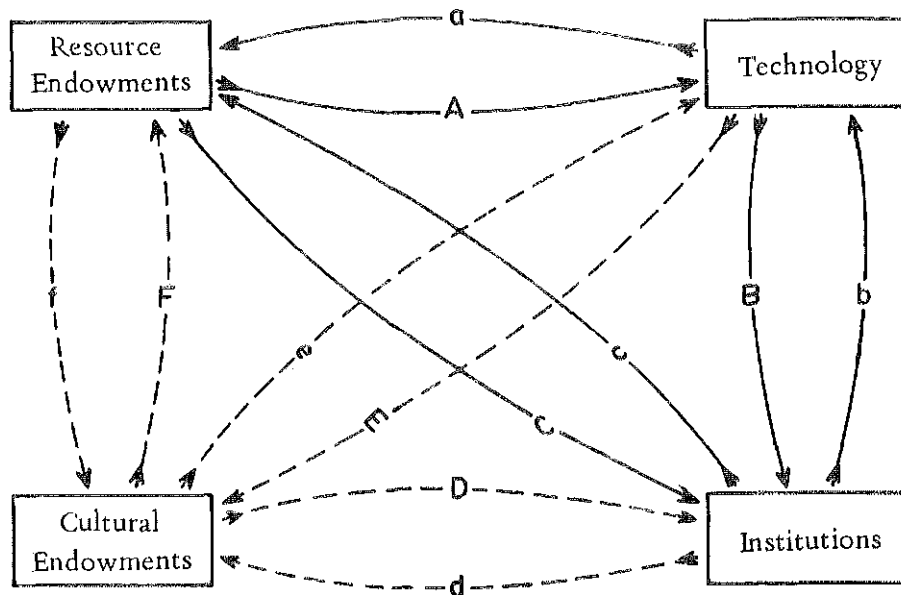


Figure 4. Interrelationships between Changes in Resource Endowments, Cultural Endowments, Technology, and Institutions.

In the study of long-term social and economic change, the relationships among the several variables must be treated as recursive. The formal micro-economic models that are employed to analyse the supply of and demand for technical and institutional change can be thought of as 'nested' within the general-equilibrium framework of Figure 4.

One advantage of the 'pattern model' outlined in Figure 4 is that it helps to identify areas of ignorance. Our capacity to model and test the relationships between resource endowments and technical change is relatively strong. Our capacity to model and test the relationships between cultural endowments and either technical or institutional change is relatively weak. A second advantage of the model is that it is useful in identifying the model components that enter into other attempts to account for secular economic and social change.

For example, historians working within the Marxist tradition often tend to view technical change as dominating both institutional and cultural changes. In his book, *Oriental Despotism*, Karl Wittfogel views the irrigation technology used in wet rice cultivation in East Asia as determining political organization. In terms of Figure 4, his primary emphasis was on the impact of resource endowments on institutions (C) and (B).

A serious misunderstanding can be observed in contemporary neo-Marxian critiques of the 'Green Revolution'. These criticisms have focused attention almost entirely on the impact of technical change on labour and land tenure relations. Both the radical and populist critics have emphasized relation (B). But they have tended to ignore relationships (A) and (C).

Why have the scholars working within the Marxian or other radical political economy traditions tended to attribute changes in property rights and income distribution to technical change which, in a more comprehensive analysis, appears to reflect the impact of changes in resource endowments — particularly the changes in man-land ratios associated with demographic change? A partial answer to this question must be sought in the rather simple model that is conventionally employed in Marxian analysis (Figure 5). In the Marxian model, the

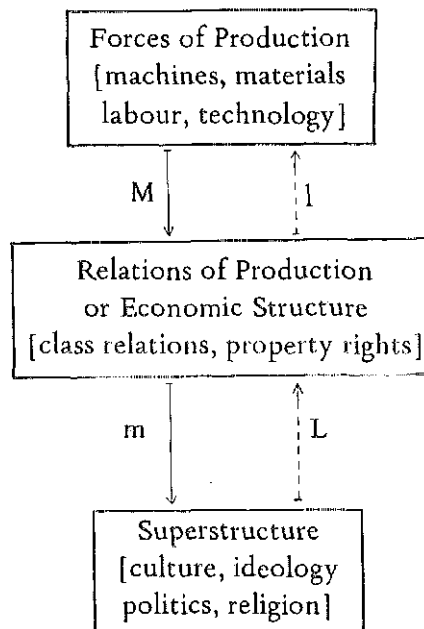


Figure 5. The Marxian Model

resource endowment and technology categories of Figure 4 are subsumed under the rubric of “Forces of Production”. It is not stretching conventional usage too much to associate “Relations of Production” and “Superstructure” in Figure 5 with “Institutions” and “Cultural Endowments” in Figure 4. There is a long history of debate over whether Marx was a technological determinist as reflected in (M) and (m) in Figure 5. It is quite clear that Lenin’s view of the relationship between the superstructure, the relations of production and the forces of production gave substantial weight to relations (L) and (l).

It does seem clear that many of the critics of the Green Revolution have conducted their analysis encumbered by ideological blinders. This blindness traces back to the debates between Malthus and Marx. The result has been repeated failures to effectively identify the separate effects of population growth and technical change on the growth and

distribution of income. The analytical power of the more complete induced-innovation model was illustrated in the work by Hayami and Kikuchi, discussed earlier, on the impact of both technical change and population growth on changes in land tenure and labour market relationships in the Philippines.

American scholars such as Armen Alchian and Harold Demsetz, working within what has come to be called the "property rights" paradigm, identify a primary function of property rights as guiding incentives to achieve greater internalization of externalities. They consider that the clear specification of property rights reduces transaction costs in the face of growing competition for the use of scarce resources as a result of population growth and/or growth in product demand.

Douglass North and John Paul Thomas, building on the Alchian-Demsetz paradigm, have attempted to explain the economic growth of Western Europe between the years 900 and 1700 primarily in terms of changes in property institutions. During the eleventh and thirteenth centuries, the pressure of population against increasingly scarce land resources induced innovations in property rights that in turn created profitable opportunities for the generation and adoption of labour-intensive technical changes in agriculture. The population decline in the fourteenth and fifteenth centuries was viewed as a primary factor leading to the demise of feudalism and the rise of the national state (line C). These institutional changes in turn opened up new possibilities for economies of scale in non-agricultural production and in trade (line b).

In a more recent work, Mancur Olson has emphasized the proliferation of institutions as a source of economic decline. He also regards broad-based encompassing organizations as having incentives to generate growth and redistribute incomes to their members with little excess burden. For example, a broadly based coalition that encompasses the majority of agricultural producers is more likely to exert political pressure for growth-oriented policies that will enable its members to obtain a larger share of a larger national product than a smaller organization that represents the interests of the producers of a single commodity. Small organizations representing narrow interest-groups are more likely

to pursue the interests of their members at the expense of the welfare of other producers and the general public. In contrast, an even more broadly based farmer-labour coalition would be more concerned with promoting economic growth than an organization representing a single sector. But large groups, in Olson's view, are inherently unstable because rational individuals will not incur the costs of contributing to the realization of the large group programme — they have strong incentives to act as "free riders." As a result, organizational 'space' in a stable society will be increasingly occupied by special interest 'distributional coalitions.' These distributional coalitions make political life more divisive. They slow down the adoption of new technologies (line b) and limit the capacity to reallocate resources (line c). The effect is to slow down economic growth or, in some cases, to initiate a period of economic decline.

What are the implications of the theory of institutional innovation outlined in this lecture for the research agenda on the economics of institutional change? In our research on the direction and rate of technical change, we were able to advance significantly our knowledge by treating technical change as endogenous — as induced primarily by changes in relative resource endowments and the growth of demand. We have also attempted to develop a theory of induced institutional innovation in which we treat institutional innovation as endogenous. There is now a significant body of evidence that suggests that substantial new insights into institutional innovation and diffusion can be obtained by treating institutional change as an economic response to changes in resource endowments and technical change.

We also insist on the potential significance of cultural endowments, including the factors that economists typically conceal under the rubric of tastes and that political scientists include under ideology. But our capacity to develop rigorous empirical tests capable of identifying the relative significance of the relationships between cultural endowments and the other elements of the model outlined in Figure 4 is nowhere near as satisfactory as the econometric analysis that has been used to test the induced technical change hypothesis discussed in my first lecture.

Until our colleagues in the other social sciences provide us with more helpful analytical tools, we are forced to adhere to a

strategy that focuses primarily on the interactions between resource endowments, technical change, and institutional change. The strategy suggested here does not have the clear advantage of allowing us to explore how far a strategy based on the rather straightforward extension of standard micro-economic theory will take us in the analysis of both technical and institutional changes.

### DISCUSSION

*Dr (Miss) Sabiha Hafeez:* As far as I have understood, there are two conceptual ingredients of institutional induced change; or, particularly talking of institutions, we have two conceptual ingredients that you have mentioned in your theory or model. One is the norms governing individuals' behaviour and the other is organizations, although it is not clear to me whether you are referring to organizational behaviour, or the norms governing organizational behaviour, or to the structure of organizations. On the basis of the examples which you have mentioned in your lecture, especially historical examples, like that of Thailand or contemporary examples like that of the Philippino villages, my basic question is about what you think are the required attributes or the required characteristics of organizational behaviour or of individual behaviour needed for inducing effective institutional change. I think that answers to these questions will really help to clarify the whole concept of induced institutional change. I mean that when you talk about induced institutional change, do you mean to say that induced institutional change involves conscious, deliberate, collaborative rational efforts to either change the existing institutions or to produce new institutions? Or, are you just talking about the environmental impact of factors like technology on the institutions? This is the basic question; and then, of course, I was very pleased that you mentioned this variable of cultural endowments, because I have been telling my colleagues here in Pakistan, particularly the economists, that they ought to include sociological variables in their analyses of economic problems. Have you worked out any meaning of cultural endowments? What are the salient conceptual ingredients of these variables? Are you looking at cultural endowment as a factor facilitating induced institutional change or do you look at it as a constraint on induced institutional change?

*Prof. Vernon W. Ruttan:* You have asked me a lot of questions. I am not sure that I will be able to give satisfactory answers to them all. Let me first take the issue that you raised about the relationship between the concept of induced innovation and what we might think of as planned social change. I am interested in understanding the process of institutional change so that I can use that understanding in planning. It seems to me that if I can understand the forces (and in my work these have been primarily economic forces) that make institutional change viable, then one can say a little bit more about how to design institutional changes that are economically and socially viable. I frequently hear discussions in which institutional failure is attributed to lack of political will. But political will is an empty concept. We need to think about the consistency between changes in resource and cultural endowments and the design of technology and institutions. What kinds of institutions does it pay to invent? We need to establish a closer articulation between analysis and design. By and large, social sciences do not give enough attention to design problems.

I see the issue of individual behaviour, norms and institutional constraints on social behaviour as somewhat analogous to the difference between internal and external economies of scale. The norms that are accepted in social life during one period may have been generated within particular organizations, such as organized religion, during an earlier period. It seems to me that we need to be able to assess how the success of particular organizations affects the broader culture. If we confine ourselves only to the broader norms, we are going to miss some of the dynamics. If we did not look at what has been happening to changes in land tenure and labour relationships at the micro level within the Philippines village, we might not be able to understand, a decade later, what is happening in the whole Philippine agricultural economy.

Cultural endowments are inherited from the past. As institutions change, those endowments also change. The institutional changes in this period will result in different cultural endowments in the next generation. Cultural endowments can represent either a constraint or an opportunity. Cultural endowments may represent a constraint on institutional transfer. They may also represent opportunities for institutional design. For example, the cultural endowments of a Chinese village, in which every

family may have a common ancestor, may create opportunities for co-operation. The early post-war literature looked at cultural endowments as constraints. It was held that new nations "must break the yoke of custom and tradition" if they were to modernize. A more valid view is that we have to use what we inherit for the design of institutions. Just as we have to design technology consistent with our research endowments, we must also design institutions that are consistent with our cultural endowments.

*Prof. Mian M. Nazeer:* May I first of all say how happy I am to see that the subject-matter of the Professor namely, Agricultural Change and Development, effects the change and development in his own thinking also. Prof. Ruttan's literature of the mid- and late-Seventies treats innovations more in the atomistic sense. I was happy to note now that he would allow other exogenous factors to come into his analysis but my hope was that this was a change of heart. As I heard the lecture and listened to the discussion, I have a feeling that it was a good lawyer's trick to extend his argument, to support and defend his original point. As long as he goes on dichotomizing the forces of demand and supply and what lies behind those two forces of demand and supply, we are heartened. But when he synthesizes them and takes innovations as such, and then endogenises them once again by keeping them pinned down to the micro-economic framework and sums up by saying that they are more by way of economic responses, then one starts wondering. My second comment is about the model itself. As you said, you have been drawing upon some stories and that also within the framework of certain institutions, which, of course, leads to the inevitable conclusions. Now, that is very fine, very educative. When we look at the model of institutional innovations as an explanation of what has been happening, there is always a danger of taking a model like this as a guideline for effecting changes, and then there is a different story which has not been told as yet. It is a different context which has not been explained as yet, which is not as yet a part of a model like this.

My third point is about the relationship in the less developed countries like Pakistan between technical change and institutional innovations. In your discussion, it seems as if the technical change necessitates institutional innovations. So far, so good. But sometimes when you have the "tops down" approach, you see that the induction of



technology from outside may have at least a short-term effect of success and light-heartedness and may in fact deprioritise institutional innovations, although necessitating them in the long run. The immediate effect may be that we have a change, in spite of the institutions being what they are, rather than because of any change in institutions. And I use the word not in the sense of your institutions being organizations but in the sense of institutions being a set of relationships.

*Prof. Vernon W. Ruttan:* The first issue you raised is the reductionist approach versus the holistic approach. My own approach is to try to work back and forth between these two approaches. In order to understand things, I have to tear them apart. I have to use a reductionist approach. That is why I try to enter the black box of institutional innovation through the mechanism of supply and demand. But, if we are going to use that knowledge for the design of institutions, we have to put things back together again. And that's not always very easy.

Perhaps you were saying that I put too much emphasis on the role of economic forces in generating institutional change. I do that, not because I believe that economic forces are the only forces operating, but because I have some tools that enable me to begin to understand the effect of economic forces on the process of institutional change. Economic forces do not determine institutional changes any more than they determine technical changes. They do influence the rate and direction of institutional change, if I were a Marxist, I might give them an even stronger role. You may remember that Marx said that water gives you the feudal lord, and the steel mill gives you the industrial capitalist. In the Marxian model, there is a linear relationship running from the forces of production to the relations of production and to the superstructure (Figure 5). If you compare the Marxian model with the induced innovation model (i.e. Figure 5 with Figure 4), the forces of production are somewhat analogous to resource endowments and technology. The relations of production tend to be identified with institutions. The superstructure tends to be identified with cultural endowments.

Figure 4 is a more realistic way of looking at the processes involved in development. From an econometrician's point of view, Figure 4 is a nightmare. In doing econometric work, we like to know which are the

independent variables and what are the dependent variables. In this kind of a model, with relationships running in every direction, it is difficult to identify the independent and dependent variables. In the short run, the relationship running from resource endowments to technical change may be dominant. But, in the longer run, the relationship running from technical change to resource endowments may be dominant.

*Mr Jsrar-ul-Haq:* I must thank you, Prof. Ruttan, for the message of hope that you have delivered. This message is that we are no longer trapped by the scarcity of resources so long as we can develop our knowledge, both the knowledge in the physical sciences and the knowledge in the social sciences. We economists were most of the time dealing with the allocation of resources arising out of scarcity. Now you seem to suggest a way out, that so long as we can take up the challenge, through institutional responses and technical changes, we can get over it. That, to me, comes as a message of hope and I welcome it. But, it lands us in a serious problem because there is hardly anything which you have left untouched. Prof. Naqvi remarked the other day that you have never given agricultural economics a moment's rest. I find that you have also not given even culture and religion and ideology a moment's rest.

I have listened to your lecture very carefully. It has got a very heavy ideological overtone and you have yourself rejected Samuelson, who said that culture, religion and ideology, which constitute a restraint on the economic variables, must not be studied by economists and that we must take them for granted. You have not only rejected Samuelson but you have said that he is a conventionalist and a traditionalist. The beauty of his economics was that you could get somewhere. You take certain things for granted because you cannot build up a model unless you take something for granted, and then you can manipulate the variables within a certain framework. Now, you have challenged the whole thing. Everything is variable. Everything is interactive and what you yourself call a nightmare for econometrics is also the nightmare for the common man. I will now read out the ideological overtones of your lecture. You have said that institutions, like technology, must change and develop if development is to occur. You have yourself further stated that culture and religion, too, are institutions. Now it is very much a nightmare to us, who believe in revealed truth that there are certain things eternal for the

human being, and you say that so long as any institution comes in conflict with any product demand, it must change. Now, the point is that most of humanity, whether or not they are practising religion, do believe in some eternal values and in some revealed truth; some basic truth like beauty, like justice, like happiness and so on and so forth. Now, these faiths and these institutions and these ideological moorings cannot be sacrificed at the altar of growth. That is in itself an ideology, unless you want to install the goddess of economic growth in the temple of economic analysis and ask the votaries to bow down before it. So, what you are doing is that you are substituting one god by another god, because, in this case, economic growth appears to be an end in itself and an end to which everything else is a means; everything else can be changed and can be modified to achieve that economic end that is economic growth. Now, economists themselves have challenged the beauty and the efficacy of economic growth because they now feel that a man must grow. I come from the Manpower Institute which deals with human resources. Now, do you think, if the rate, of economic growth is increased tremendously, human resources too will increase? It will create a better man. Now, unless you subscribe to this view, you cannot make economic growth to be an end in itself. You are rejecting the cultural and religious ideology. You are installing another ideology in its place, the ideology of economic growth. Now, I will give you one example. Suppose, in America, there is a great demand and there is great clamour that all the smuggling of narcotics must stop and very rightly so. Now, if there is a genuine effective demand for narcotics, or hashish, in America, will that be a sufficient ground for you to shift your lane from wheat growing to hashish or opium growing? Will you do that? Will you make some institutional response? Will you take over all the laws which prohibit the smuggling of that? No, you are not going to do that. Why? Because you think that the taking of narcotics by your young is something undesirable in itself. That is why instead of institutions responding to this demand, the institutions are stepping in to stop this demand from making itself felt in the market. So that is why I say that you are installing another god, the god of economic growth, without going through what the limitations on that are. If everything is to change in a system where nothing is taken for granted, such a fluid state of affairs raises very difficult questions. What is the destiny of man? What is the concept of man? Unless those problems are solved, I am not prepared to accept that economic growth is the end of all this. So that is why I

say that the economic model that you have built is not capable of making any recommendations in a society which believes in certain eternal truths. For example, we are a society that believes in certain truths. Now the Americans too are moving towards belief in certain eternal truths. They are not prepared to sacrifice those truths for the sake of economic growth. So in this world we are now moving towards something that is divine, that is something that we can take for granted. For example, family and marriage are two institutions which have to be sacrificed at the altar of industrial development. Bertrand Russell said that industrial civilization would require that women should share their children not with their husbands but with the State and now you find that marriageless motherhood is becoming common. Surrogate mothers are becoming common. But do you think that we are going to accept that only because it is going to accelerate economic growth? We are not. We are not going to change the institutions of marriage and family for the sake of economic growth. So these are the limitations within which your model is framed, and kindly realize that you have tried to overthrow a certain ideology and in the place of that you have introduced another ideology and that this model is far from being empirical, far from being pragmatic, far from being practical. It is highly ideological in content which rejects all other ideologies. Thank you very much.

*Prof. Vernon W. Ruttan:* You have raised some very complicated and very important questions. Let me turn first to an area of agreement that is in our hopes for the future. What I am saying is that it is possible to substitute knowledge for resources. That is much more optimistic than the economic and other social science models which we inherited from the past and which tend to look upon culture as a constraint.

I am not arguing that a society should choose to give up its fundamental institutions. But it should think ahead and ask if it is making implicit choices that will end up in causing it to change its religion and not realize it until after it has happened. I am not quite prepared to accept your criticism that I have attempted to impose a new ideology. I am attempting to say that we need to think through the whole set of relationships that we have discussed in making those choices. This is related to a point I made over and over again. It's not an invisible hand that determines the future. We have the possibility of making choices.

These choices are often very difficult because doing what is good is not always the same as doing what is right; and doing what is bad is not always the same as doing what is wrong. Doing what is good may be wrong if it is not the best you can do. And doing what is bad may not be wrong if it's the only way you can avoid doing something worse.

I think you brought up the issue of drug use. I would like to use another example, that of alcohol use. In the 1920s, the United States prohibited the use of alcohol. I would still like to see alcohol use stopped in the United States. But our experience was that an attempt to do good by stopping alcohol use corrupted the law enforcement system. The bad that prohibition was doing was more than enough to offset the good. That is the kind of world we live in. I do not see very many societies that are willing to reject growth. They are hoping that they can grow without experiencing the cultural changes that will accompany growth. That is somewhat blind. If a society chooses growth, it is going to have to choose to live with certain cultural changes that come along with growth. But I agree with you that we should make those choices explicitly and not leave them to a hidden hand.

*Dr M. A. Hussein Mullick:* Today naturally your lecture was slightly more clear than yesterday's and Mr Israr-ul-Haq has already asked a lot of questions on a front which you perhaps understand better and so also does Israr-ul-Haq. We economists are more earthly. I think economists have been too quick to accept concepts such as take-off, without remembering that there were many things that actually happened in Europe and elsewhere which brought this whole development into being and I think unless we go into that exercise, it is possible that we may have some semblance of development but we may continue to suffer from the same Asiatic mode of production that Marx mentioned and you also noted. I personally feel that in Pakistan we have this military and bureaucratic incubus which has prevented the capitalist system from emerging. Other societies like Japan and South Korea, in fact, were able to succeed because they first tried to break the stranglehold of the tradition trap. And I think there are many problems which must be understood at the country level, and if you generalized things too much, then the results of such an analysis could be highly misleading, could be

catastrophic. My second point is about the romantic view. I can assure you that the fact that I am sitting in this hall is due to my romance with history. I think your view of a romantic is again, maybe, of a too agricultural nature but not going beyond that. I can assure you that we in Pakistan are now struggling with the Islamization efforts. We are doing it on the banking front and I am one of those two people back in 1960 who, in fact, thought up this system, but that was romance. If there had been no romance, then why did we realize back in 1960, in Germany, that the type of development system that we took over from Europe was not being accepted by the people. So, the cultural endowment that we had was going against it. The institution of interest, for instance, was rejected and it was imposed on us by an alien government with an alien system. So, if there is no romantic view of the past, I think this present may not be worth living. I can assure you that I have studied South Korea and Japan and I do not think that they have lost track of their romantic view of the past. In fact, that has helped them to take the new model, to change it to their own taste, and as a consequence they have been able to develop. I do not think that ideas, ideology or religion are something which should be rejected out of hand. There is a lot of merit in this, otherwise Max Weber would not have been born, and so also Dirk Hyme and several other sociologists. I think they have proved beyond doubt that this romantic view and this ideological and religious view is important and can bring about the social change that you talked about.

*Prof. Vernon W. Ruttan;* I think we are very much in agreement. If I can interpret what you are saying in terms of my terminology, you are saying that the cultural endowments of an idealized Islamic Society need to be taken into consideration in the design of economic institutions. In taking them into consideration, one may have quite different economic policies and different economic institutions from those in a society in which the cultural endowments were dominated by different traditions.

Yesterday I stressed that in the area of technological change there is a unique path of technical development that is appropriate or viable for a particular society. I view institutional change in the same way. I do not think that there is one Western path of technological change. Nor do I believe that there is one efficient Western or Eastern path or model of

institutional change. I would argue that each society should design its own institutions in a manner that is consistent with its cultural endowments.

*Mr Rao M. Suleiman:* I am sorry I could not attend Prof. Ruttan's lecture yesterday which might have been more relevant for me; but I have some observations to make on what he said in the very beginning today and which seems to be at variance with our experience in Pakistan. One very important observation he made was that technical change was largely endogenous. When we look at the Pakistani scene, whatever agricultural development has taken place here since the introduction of the high-yielding variety seeds and the use of water and fertilizer has had a long background behind it. But I am talking about fertilizer which I am more familiar with. Back in 1880, the total fertilizer use in the world was less than what Pakistan is using today. In 1925, it was less than what India is using today. Then, of course, there was the war. There were many developed countries which experienced war and hunger. There were certain others which started producing more ammonia than was needed for munitions and had to find their use in agriculture through ammonium nitrate, and then as soon as the war was about to close, they realized that unless they find a wider market for it, a lot of investment will go waste. (That is why we have in Pakistan institutions like CIMMYT.) Later on, IRRI and high-yielding varieties were developed and were spread throughout the world that created demand for fertilizer, to begin with, for nitrogenous fertilizer in which the war-time surplus capacity was there. Then the fortunes took another turn and, as we see today, the United States is the second biggest importer of urea and nitrogenous fertilizer and a big importer of ammonia. So the balance shifted towards balanced fertilizer use, that is more use of phosphates than had been practised in most of the countries. In the recent past, yet another change has come in phosphates also. The USA has been taken over by Morocco, by Tunisia, by Turkey and by a number of African countries, and we are hearing of inoculation of and bio-technology application to the seed. How can then we accept the idea that technical change is endogenous? It is coming from outside and it is meeting more the needs of the big brothers in the outside world than the real needs of the countries where the technical changes are coming. It is also clear in the matter of detail. If you have to use fertilizer from abroad, it has to be a high-quality fertilizer even

though it involves heavy losses in the course of use. That is why we have urea, we have DAP and things like that. There are, on the other hand, countries which are having this technical change as an endogenous process. China, for instance. Most of the fertilizer used there is ammonium bi-carbonate with a concentration of only about 12 percent compared with 64 percent in DAP. DAP is 64 percent because it has to travel long distances to reach the fields in Pakistan, and the Chinese manufacture it by the roadside, and even 12 percent does not pose any problem of heavy transport costs. That is one question.

The other question is about the scarcity of land and man. Most of the institutions that existed in Thailand in the olden days perhaps still exist there. Girls are still sold there. Their land frontier perhaps has not yet been reached. Over any period, the increase in the net area sown is equivalent to the net area deforested. They are doing it pretty fast. About 50 years back, 50 percent of their total area was forested. Today, the official figures are about 15 percent but everyone knows that a lot of area classified as forests is in fact subjected to crop production. Only the records have not been suitably changed. It is the same position in the Philippines and, in a more *org^mzcd* way, it is being done in Indonesia, which has the capacity of doubling its sown area over the course of the next generation or so by reclaiming some of the hydraulic soil. But as far as Pakistan is concerned, this endogenous thesis does not seem to hold. Nearly 48 percent of our planned agricultural production during the Sixth Plan period will come from use of fertilizer. If we add to that the variety of seed, it might well be close to two-thirds. So, it largely depends on what is being done abroad. Every five or seven years we have to renovate our varieties and the entire purpose of research is just to adopt those varieties and to multiply the seeds. Thank you.

*Prof. Vernon W. Ruttan:* I appreciate that comment. It gives me a chance to clarify a bit. I like to think of technology transfer under three broad headings. One is what might be called *material transfer*, if I bring ammonium nitrate from one country to another I am simply transferring material. When the original Mexican seeds were brought to the Indian and Pakistani Punjabs, that was a material transfer. The next stage is *design transfer*. When a design of a new machine is brought here and is produced here, rather than the machine itself, that is design transfer. The third is *capacity transfer* — the capacity to invent.



Now it was not an accident that wheat varieties available in the United States were not able to generate increased production in Mexico. It was necessary to develop varieties in Mexico that were resistant to the kind of wheat rust that existed in Mexico. The breaking of the photoperiod sensitivity occurred as a result of the breeding practice in Mexico. It was something of an accident that the Sonora area in Mexico was similar enough to the two Punjabs for a direct transfer of the Mexican varieties to them. But I do not think you are still using the Mexi-Pak variety now. If you are, you should not be. If you are, it is a reflection of the failure of your own research institutions. The countries that are getting the most out of the new varieties have been able to take those original varieties and replace them with the varieties that are adapted to their own environments. You have strengthened the research institutions at Faisalabad. And not only that, you are building applied research centres at other locations to carry out the fine-tuning of that technology. So I do not think that we are that far apart. To get the most out of that technology, that prototype technology, you had to develop your own research capacity. If Pakistan did not have its own research capacity, it would be very vulnerable.

The increased use of fertilizer was made possible by the development of those varieties. The varieties of wheat that we had in the United States, the varieties of wheat that they had in Mexico, and the varieties of rice that were available in the Philippines, before the new varieties, were not fertilizer-responsive. They were vegetatively responsive but not responsive in grain yield. Those plants had to be redesigned to use that fertilizer. In an open world, there will be some material transfer when appropriate, but, by and large, to get the productivity out of the material, we have to have the ability to adapt the biological technology to our own environments.

*Dr Abdul Salam:* I have one observation which is partly related to the comment which you made yesterday pertaining to the Green Revolution technology characteristics as being neutral to scale or neutral to size and partly to the observations which you made today that this technical change does introduce certain forces which set in motion changes in the factor endowments as well as on the institutional fronts. This technology which we have popularly dubbed Green Revolution, as I said earlier,

has been neutral to scale, but it does set in motion changes in the tenurial institutions and size distribution of holdings and changes on the front of mechanization which I feel have certain implications for income distribution. I would like to have your reaction to that. Thank you.

*Prof. Vernon W. Ruttan:* In order to answer your question we must again refer to both technical change and institutional change. Rarely in the history of the world have we invented a technology that is more available to the small farmer than the Green Revolution or seed-fertilizer technology. It is a highly divisible technology. We cannot really say that about mechanical technology, although it is more divisible than we have sometimes made it. The Japanese have designed a very divisible mechanical technology. Pakistan and India should be ashamed of themselves for not having made available small mechanical equipment to their small farmers. The assumption was that large tractors were more efficient and therefore that's what farmers should have.

In the case of the Green Revolution biological technology, we have invented a highly divisible technology. But we have introduced it into societies in which institutions have been biased against the small farmer. A number of simple-minded analysts have said that the technology was causing the bias. Now, when you have a system of charging for irrigation water that is biased against the small farmer, when you have a system of access to credit that is biased against the small farmer, and when you have a land tenure system that is biased against the small farmer, one should be very careful about attributing the bias against the small farmer to technology. It is important that we diagnose correctly if we are going to introduce the changes necessary to correct the problem. As social scientists, we should have been diagnosing the institutional biases against the small farmer instead of sitting around complaining about the biologist, the agronomist, and the plant breeder.

*Dr Akhtar Hasan Khan:* I tend to agree with Prof. Ruttan that cultural endowment is an inheritance of the past and that it is determined by religion, history, sociology and other things; but, taking a cross-sectional point of view, would he agree with the view expressed by some people that Confucian culture is more adept in adopting technological changes and making institutional changes than the culture of Southeast Asian

countries, and would he agree that the rapid growth made in East Asian countries as compared with South Asian countries in the last 25 years is mainly due to differences in their culture and institutions?

*Prof. Vernon W. Ruttan:* I think it is an extremely important question and I wish I knew how to get the answer. But we have to be very careful about too facile an explanation. I recently read a book that attributed the decline of industry in the U.K. to the "gentrification" of the new industrial classes. That's the kind of cultural explanation that is awfully easy to make but hard to test. I cannot help but believe that the differences between South Asian culture and East Asian culture do make a difference. But I do not know how to analyse those differences in such a way that two different scholars, with different viewpoints, could arrive at the same conclusion. There is a real gap in our analytical capacity. There is a series of explanations, one of which could be cultural. Many people emphasize the impact of the Korean War on industrialization in East Asia. There are a number of explanations and I do not think we really know how much weight should be given to each.

*Dr Faiz Mohammad:* I have two short questions. One is about the relationship between technical change and the institutional innovations and then about the relationship between cultural endowment and the other variables in your model. It is very important to understand first of all the direction of relationship which you have very correctly specified although you have later on pointed out that it is not clear which one is the independent and which one the dependent variable. I think, beyond that there are three other things which are important to understand from the set of relationships in your model. The first is the speed of relationship. Why is that important? It is because that will perhaps determine where the market-induced forces have generated some institutions and where there is a need for public-sector intervention and then naturally the magnitude of relationship. Taking these two things into account will perhaps determine the criteria which can be used for public-sector intervention in creating certain institutions. That is my first question.

As for my second question, I do agree with Mr Israr-ul-Haq when he says that this whole thing in fact also represents an ideology because this

seems to give an impression that this is how the society can be transformed because you have also taken into account the technology, the institution, the cultural endowment and so on and so forth. Then, if we look at these four pillars which you have drawn in your table, the question arises, from where to start first. Should we explore the cultural endowment first to bring about institutional innovations or vice versa? There I will like to make another point which I somehow cannot understand, and that was the question of political will. I think that the political will may also be part of cultural endowment because the way I understand it, political will itself could be a response to the way the society would like to change different institutions which are desired from time to time. So really you cannot exclude political will from cultural endowments.

*Prof. Vernon W. Ruttan:* The models I put on the board do not provide any answers or policy guidelines. They represent diagnostic tools for looking into the system -for looking into the black box. And by reducing our ignorance, so that we can see how things are related to each other, we can take into account those relationships as we design our policy. I again come back to the viewpoint that policy design needs to be specific to the resource endowments and the cultural endowments of a society. On the political will issue, I am partly in agreement with you. Perhaps I am a cynic, but my own view is that a society cannot depend upon good rulers. Political systems throw up ambitious men rather than good men. The system of governance — the harness we put on those men — determines whether those ambitious men do good things. Cultural endowments undoubtedly influence the kind of political systems we must design to harness our leaders so that they pull the cart to generate growth — or whatever objectives society may have. We cannot simply depend on the political will of good men. If they were just good men, they would not rise to leadership. To rise to leadership, they must also be ambitious men.

*Prof. M. Rashid:* Prof. Ruttan, we had a little discussion last evening in the corridor. In this morning's lecture and yesterday's lecture, the wide coverage of countries seems to exclude from your study and observation China, the biggest country in the world in terms of population. It is a very curious omission. Since 1949, a lot is happening there and since 1980-81, modernization programmes have been set in motion. The

Chinese pragmatism in introducing changes in institutions and developing technical knowledge have been documented here and there. I was wondering if you would care to comment on the Chinese development experience since 1949 and what lessons, if any, it might have for what you call the folly committed in South Asia.

*Prof. Vernon W. Ruttan:* You are correct that I have omitted China. I also omitted the rest of the socialist world. Within the last couple of years, I have been able to begin to work with some students on agricultural change in the centrally planned economies. We are beginning to try to test the induced innovation model against the experience of socialist economies. If planning is a perfect substitute for the market, then we should find that, given their resource endowments, the Chinese experience looks very much like the Japanese experience, and the USSR experience looks very much like the U.S. experience. If the kind of planning the socialist economies have engaged in has distorted the signals that they have given to their engineers, agronomists, scientists, and managers, then we should see some quite different relationships between resource endowment and technical change. We have some very difficult problems in this research. For example, how does one obtain some indicators of the scarcity of land in a country in which there are no markets for land? We are going to have to design some surrogate measures. I am going to spend six weeks in China in May and June, and one of the things I want to look at specifically and that I want to try to understand is the Chinese agricultural research system,

*Dr Sarfraz Khan Qureshi:* The message to me of the induced institutional innovation model is that rural people, faced with problems and challenges, have in history and in contemporary times responded effectively to maximize their welfare, howsoever defined and/or measured. They have adapted their economic behaviour, They have also modified the institutions to serve their ends better. I wonder whether the induced innovation model can be extended to a situation in which the real villain for the rural poor is an adverse external environment in the form of unresponsive national and/or provincial government or the international community. I think most governments in the developing countries are dominated by what is generally called in literature a military-bureaucratic set-up. These governments do not let the people

organize themselves and throw up their demands in the political sphere and/or in the economic sphere. In such situations, policies made for the agricultural sector are generally a victim of expediency and serve the interests of vested groups. Sometimes the policy-makers stress pricing packages of one kind or the other and at other times they may be emphasizing particular kinds of technology policy. At yet other times, they may have a fascination for a particular sort of institutional innovation. The rural scene in Pakistan has been a victim of an adverse external environment which has translated itself into policy instruments that give contradictory signals to farmers. What I would like to really know is why the induced innovation; „ model does work in the political field when the existing power imbalance is maintained and the system becomes progressively hostile over time.

*Prof. Vernon W. Ruttan:* When Prof. Hayami and I first started working on this induced innovation model, we were surprised that it worked. We picked two countries that were extremely different — Japan and the United States — for our first effort. For these two countries, the differences in resource endowments, interpreted through relative factor prices, explained a great deal about the direction of technical change. Later, as we included more countries, we began to be surprised when the model did not hold. It is no longer interesting to do this kind of analysis in a country where the process of inducement is working. The induced institutional model, which implies that institutional change is also consistent with a country's resource and cultural endowments, requires that the political market should work effectively. If the political market is biased, if somebody is holding his hand on the thermostat or is sitting on the boiling pot and keeping the lid on, then the forces that would interpret the demand for institutional change to the policy-makers will be biased and one can expect that the direction of institutional change will be biased to reflect the distribution of political power. This means that if we want to design a society in which technological development and institutional development are consistent with the nation's resource and cultural endowments, we first have to design effective economic and political markets. Another way of making the same point is that we must design an appropriate institutional framework.

**CONCLUDING  
REMARKS**

*by*

**Sohail Jehangir Malik**

## CONCLUDING REMARKS

*by*

Sohail Jehangir Malik

It seems ordained that an agricultural economist of the stature of Vernon Ruttan should use the forum of the Pakistan Society of Development Economists' lecture series to talk of technical and institutional change in agricultural development. These lectures (like the theory of technical and institutional change propounded by Prof. Ruttan) are an 'induced' and 'endogenous' product of the process of intellectual interaction and development initiated in 1982 when the Pakistan Society of Development Economists was founded.

The large attendance at the two lectures and the question-and-answer sessions that followed bespeaks the relevance of the topic and the level of awareness of the issues involved. Prof. Ruttan is one amongst many who have been predicting that by the end of this century all increases in world food production will come from higher yields, i.e. increased output per hectare, implying a transition from a resource-based to a science-based agriculture. This increasing emphasis on 'land-saving' technology for increasing productivity and production has resulted from the growing population pressures on land and declining land-man ratios.

Within the context of overall economic growth, there has been, during recent decades, a sharp transition in economic doctrine with



respect to the relative contributions of agriculture and industrial development. There has been a shift away from the earlier 'industrial fundamentalism' to an emphasis on the significance of growth in agricultural productivity and production. The focus, especially in the context of the present-day less developed countries like Pakistan, has sharpened with the rapid growth in demand for food resulting from the increasing growth in population and the high income-elasticities of demand for food.

Prof. Syed Nawab Haider Naqvi has, in his introductory remarks, in his usual inimitable style, provided an extensive overview of Prof. Ruttan's numerous contributions to the body of knowledge on agricultural economics and of how this work correlates with the evolution of the major themes in development economics. It remains for me merely to provide a summary of Prof. Ruttan's two lectures on "Technical Change and Agricultural Development" and "Towards Induced Institutional Innovations" and to highlight the major conclusions, especially those that relate to the process of agricultural and economic development in Pakistan.

Prof. Ruttan has classified the traditional literature on agricultural development, historically, into five headings or 'models'. Traces of the essential characteristics of each one of these models can be found in the economic thought and in the policies adopted at different times in Pakistan. The much-publicised agricultural revolution in Pakistan during the Sixties was based largely on the logic underlying the high-payoff input model. This model assumed that peasants in traditional agriculture were rational, efficient resource-allocators constrained to poverty only by the limited technical and economic opportunities to which they could respond. The earlier success of this model was based upon the development of high-yielding grain varieties for the tropics, which were highly responsive to fertilizer and improved soil- and water-management. The fundamental ingredients of the high-payoff input model are classified by Prof. Ruttan as (i) the capacity of private- and public-sector research institutions to produce new technical knowledge, (ii) the capacity of the industrial sector to produce and market these new technical inputs,

and (iii) the capacity of the farmers to acquire and use the new inputs effectively.

There are several important lessons to be learnt from this model, which, though ideally conceived in the neo-classical framework, proved incomplete as a basis of a theory of agricultural development when put into actual practice. It failed to incorporate the mechanism whereby resources are allocated to those public goods that are not traded in the market. Typically, it ignored education, research and other public- and private-sector activities, the output from which can be classified as public goods. It did not provide a clear division between the spheres of the public and private sectors, making it impossible to determine a productive equilibrium between the respective roles of the 'visible' and the 'invisible' hands. In many countries, it was the inability to free the private sector to produce and market those new technology inputs in which the public sector was not as effective, while in others it was the inability of the public sector to provide those inputs (essentially public goods) that could not be produced in the market.

Lack of education and under-investment in human resources were the crucial limiting factors in Pakistan's attempts to take full advantage of the gains from the high-payoff inputs model. However, in this regard, Prof. Ruttan makes an extremely important point. Formal schooling has little economic value in agricultural production. It is imperative that Pakistan should focus its attention on redesigning the formal schooling system to make it more "need-based", besides developing an alternative system that, in addition to providing elementary literacy, also equips an individual with the workable principles of productive economic life. In this regard, Prof. Ruttan has made an extremely pertinent observation regarding agricultural extension services. He recommends that they must advance from teaching 'practices' to teaching 'principles'.

Prof. Ruttan has maintained that wide variations in land and labour productivity are due largely to the lags in shifting from a resource-based to a science-based system of agriculture and are increasingly a function of investments in scientific and industrial capacity and in the education of the rural people rather than the result of natural

resource endowments. In this regard he has highlighted the need for viable institutions capable of supporting more rapid agricultural growth and rural development. However, given the present state of the art, there is a greater insight available into the processes by which new knowledge can be applied to alter the rate and direction of technical change than the insight into the processes by which resources can affect institutional innovation and transfer.

Prof. Ruttan shatters a widely held myth that institutional change is only of the dramatic or revolutionary type anticipated by Marx and others. It can, he states, result from changes in factor endowments and/or product demand, or merely from modifications in contractual relations or shifts in the boundaries between market and non-market activities. The two lectures by Prof. Ruttan serve not only as excellent reviews of what we already know but also provide a clear definition of the hitherto dark and uncharted areas of our knowledge. His call for expanding the scope of modern analytical economics to consider institutional change as an endogenous variable in the overall model of agricultural productivity and growth is opportune. However, till such time as that can be done, and in the absence of alternative social science tools for analysis, one is constrained to use the existing micro-economic theory to study interactions between resource endowments, technical change and institutional change. As Prof. Ruttan points out, there is no knowing how far this approach will take us in the understanding of the institutional change phenomenon and, especially, the factors affecting the supply of institutional innovations.

The role of research in the induced technical change and institutional innovation model is crucial. It is clear from the experience of the past that agricultural research cannot be left to the forces of market alone. This is largely due to the non-excludability characteristic of fundamental agricultural research that makes it difficult for private-sector firms to exclude from the use of their research those who have not paid for it. The stochastic nature of the agricultural research production function also requires large outlays of investment over a number of projects in order to minimize the risk, and thus forces most of the private-sector firms to reconsider any designs of research into areas of high social priority. There is also the omnipresent problem of misallocation

of research resources in the private sector. Research funds would flow only towards those areas that can be protected by patents and trade secrets. There is thus a considerable need for the "socialization" of agricultural research, which Prof. Ruttan advocates. Public-sector institutions devoted to basic research could be a major institutional innovation designed to offset any possible misallocation of resources in agriculture research.

Prof. Ruttan in these two lectures has focused directly on the growth aspects of agricultural production, that is on the issue of raising agricultural productivity by bringing about a rapid transition to a science-based agricultural system. In it both technical change and institutional innovations are induced from within, i.e. they are 'endogenised'. But there is also the related problem of equity in the distribution mechanisms and employment generation, both of which are crucial to the overall development of nations. The extent to which the poor gain or lose from the introduction of a new agricultural technology depends on a host of complex and interrelated socio-economic and political factors such as the existing distribution of productive resources, access to modern inputs, the structure of the market, etc. While it is true that massive increases in productivity are possible and have been attained, it is also true that a significant proportion of humanity is still starving. The brutal free-market approach does not take cognizance of the enormous human costs involved. Famines have ravaged nations even in times of plenty. It is estimated that for every surplus ton of grain produced in the world there is at least one starving person! And as global grain surpluses continue to increase dramatically, so does the need to build equity aspects in the process of economic development with appropriate technological and institutional changes.

**BIOGRAPHICAL SKETCH**

*of*

**Prof. Vernon W. Ruttan**

*Appendix*

**BIOGRAPHICAL SKETCH  
OF  
PROF. VERNON W. RUTTAN**

Date of Birth:	August 16, 1924	
Education:	Michigan State University	1942-43
	<b>B.A.</b> , Yale University	1948
	<b>M.A.</b> , University of Chicago	1950
	<b>Ph.D.</b> , University of Chicago	1952
Employment:	1951-53	Economist, Tennessee Valley Authority, Division of Regional Studies, Office of the General Manager
	1954-	
	1955-57	Assistant Professor, Development of Agri- cultural Economics, Purdue University
	1957-60	Associate Professor, Department of Agri- cultural Economics, Purdue University
	1960-63	Professor, Department of Agricultural Economics, Purdue University
	1958-59 (on leave from Purdue)	Associate Agricultural Economist, Giannini Foundation of Agricultural Economics, University of California (Berkeley)
	1961-63 (on leave from Purdue)	Staff Economist, Council of Economic Advisers, Executive Office of the Presi- dent
	1963-65	Agricultural Economist, Rockefeller Foundation (at the International Rice Research Institute, Philippines)
	1965-70	Professor and Head, Department of Agricultural Economics University of Minnesota
	1967-73	Trustee, Agricultural Development Council, Inc.
	1970-73	Professor and Director, Economic Devel- opment Center

- 1973-77 President, Agricultural Development Council, Inc.
- 1978- Professor: (a) Department of Agricultural and Applied Economics (b) Department of Economics and (c) Hubert H. Humphrey Institute of Public Affairs University of Minnesota

#### Professional

##### American Agricultural Economics Association:

- Committee on New Orientations in Agricultural Economics Research, 1959—63
- Editorial Council, 1965-67
- Vice-President, 1967-68
- Committee on Professional Problems in International Research, 1967-69, (Chairman, 1968-69)
- President, 1971-72

#### Awards and Honours:

- Publication Award, American Agricultural Economics Association, 1956, 1957, 1962, 1966, 1967, 1971, 1979, 1985
- Fellow, American Agricultural Economics Association, elected 1974
- Fellow, American Academy of Arts and Sciences, elected 1976
- Honorary Degree, Rutgers University: Doctor of Laws (LLD), 1978
- U.S. Department of Agriculture, B.Y. Morrison Memorial Lectureship, 1983
- Alexander von Humboldt Award, 1984 (for outstanding contribution to agriculture over previous five years)

#### Professional and Public Service International:

- Agricultural Development Council, Inc., Board of Trustees, 1967-73, President, 1973-78
- Economics Institute, Policy and Advisory Board, 1968-1970

International Association of Agricultural Economists,  
U.S. Council Member, 1969-1972  
Consultative Group on International Agricultural  
Research, Technical Advisory Committee (TAC),  
1973-1977  
Asian Vegetable Research and Development Center,  
Board of Directors, 1975-1977  
Asian Development Bank, Co-chairman (with Kazushi  
Ohkawa), Consultative Committee on Updating the  
Asian Agricultural Survey, 1975-1977  
International Service for National Agricultural  
Research (ISNAR) Board of Directors, 1979 -  
present  
Director, UM-ISNAR Agricultural Research Policy  
Seminar, (Annual 1982, 1983, 1984, 1985, 1986)

National: Agency for International Development, Research  
Advisory Committee (RAC), 1967-1975, 1983  
Asia Society-Southeast Asia Development Advisory  
Group (SEADAG): Chairman, Rural Development  
Seminar, 1968-1969, Executive Committee,  
1969-1971  
National Research Council, (a) Committee on Prob-  
lems of Pest Control, 1971-1975; (b) Agricultural  
Board, 1983  
National Planning Association, Committee on Agri-  
culture, 1981  
Sierra Club, Economics Committee, 1983

Minnesota: Governor's Council of Economic Advisers (Minnesota),  
1971-1973  
Chairman, Committee to Review State Funded  
Research, Governor's Office of Science and Tech-  
nology, St. Paul, 1984

Member: American Academy of Arts and Sciences  
American Agricultural Economics Association  
American Economics Association  
Council on Foreign Relations  
Economic History Association  
Indian Society of Agricultural Economists



International Association of Agricultural Economists  
Philippine Economic Society  
Society for the History of Technology

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edition)
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Behavioral Sciences*, 11th Edition (New York: R.R.  
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*Plant Science: An Introduction to World Crops* with J. Janick, R.W. Schery and F.W. Woods. San Francisco: W.H. Freeman and Company, 1st Edition, 1969; 2nd Edition, 1974; 3rd Edition, 1981.

*Agricultural Development: An International Perspective* with Yujiro Hayami. Baltimore: The Johns Hopkins University Press, 1st Edition, 1971; 2nd Edition, 1985. (First Edition received American Agricultural Economics Association Publication of Enduring Quality Award, 1985.)

*Induced Innovation: Technology, Institutions and Development* with Hans P. Binswanper and others. Baltimore: The Johns Hopkins University Press, 1978. (American Agricultural Economics Association Publication Award, 1979.)

*Agricultural Research Policy.* Minneapolis: University of Minnesota Press, 1982. (Italian translation, *Politica per la Riceria in Agiicoltura*, Venezia; Giunta Regionale del Veneto, 1985.)

B. Books — Editor

*Agricultural Policy in an Affluent Society.* Edited with A.D. Waldo and J.P. Houck. New York: W.W. Norton and Company. 1969.

*Plant Agriculture: Readings from Scientific American.* Edited with J. Janick, R.W. Schery and F.W. Woods. San Francisco: W.H. Freeman and Company. 1970.

*Agricultural Revolution in Southeast Asia: Impact on Grain Production and Trade.* New York: The Asia Society. 1970.

*Resource Allocation and Productivity in National and International Agricultural Research*, Edited with Thomas M. Arndt and Dana G. Dalrymple. Minneapolis: University of Minnesota Press. 1977.

*Agricultural Growth in Japan, Taiwan, Korea and the Philippines*. Edited with Yujiro Hayami and Herman Southworth. Honolulu: The University Press of Hawaii. 1979.

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"The Changing Industrial Molasses Market". With T. N. Hubbuch. *Journal of Agricultural and Food Chemistry*. July 22, 1953. pp. 602-608.

"The Relationship Between the BAE Level-of-Living Index and the Average Incomes of Farm Operators". *Journal of Farm Economics*. Vol. 36. February 1954. pp. 41-51.

"The Impact of Urban-Industrial Development on Agriculture in the Tennessee Valley and the Southeast". *Journal of Farm Economics*. Vol. 37. February 1955. pp. 38-56. Reprinted in Karl A. Fox and D. Gale Johnson (eds.), *Readings in the Economics of Agriculture*. Homewood: Richard D. Irwin. 1969. pp. 339-358. (American Farm Economics Association Award, 1956.)

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"Agricultural and Non-Agricultural Growth in Output per Unit of Input". *Journal of Farm Economists*. Vol. 39. December 1957. pp. 1566-1576.

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