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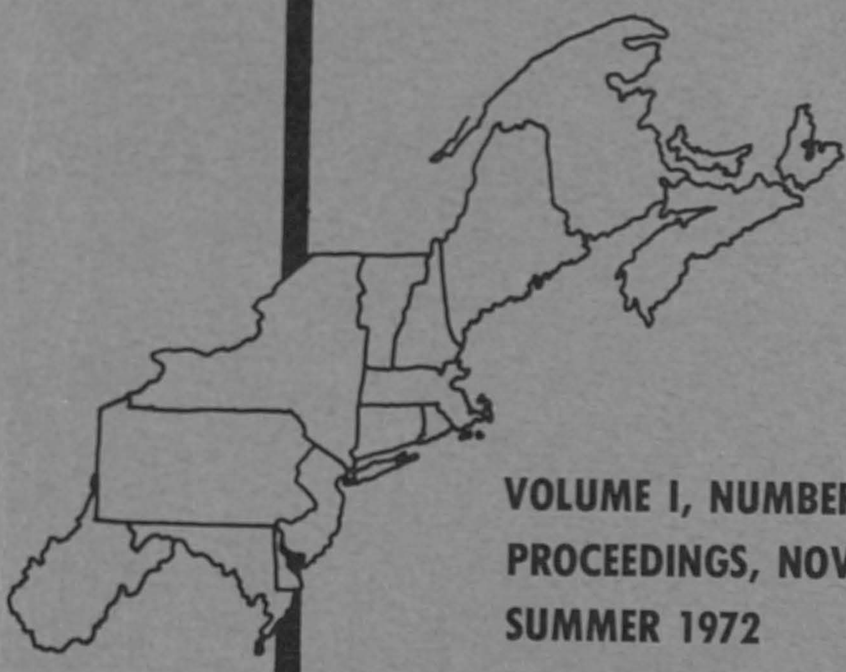

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AGRICULTURAL PRODUCTIVITY DIFFERENCES*

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Growth in aggregate agricultural output, and productivity is generally recognized as a necessary condition for economic development. The persistent differences productivity among countries and regions (Figure 1) have severely dampened the optimism among national policy makers and planners and among officials in the international aid agencies as to the possibility of substantially narrowing the gaps in productivity (total, land, and worker) in the feasible future.

In this paper an attempt is made to quantify the relative importance of the several sources of differences in labor productivity in agriculture among countries. Attention is given to both the productivity differences between the less developed countries (LDC's) and the developed countries (DC's) and to the differences between the older developed countries (ODC's) and the more recently settled developed countries (RDC's). The paper presents, as far as we can determine, the first attempt to assess quantitatively, the significance of the favorable resource endowments of the RDC's relative to the OCD's. Before proceeding to an examination of the empirical results I would like to comment briefly on the conceptual perspective and empirical methodology employed in the analysis.

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The Meta Production Function

It seems reasonable to classify the sources of agricultural productivity differences, or of productivity growth, into three broad categories: (a) resource endowments; (b) technical inputs; and (c) human capital. Land and livestock serve as proxy variables for resource endowments; machinery and fertilizer for technical inputs; and general and technical education in agriculture for human capital.

Land and livestock represent a form of long term capital formation embodying inputs supplied primarily from within the agricultural sector. In traditional systems of agriculture internal labor intensive capital formation represented almost the only source of growth of labor productivity. Fertilizer, as measured by nutrient consumption in commercial fertilizer, and machinery, as measured by tractor horsepower are employed as proxies for the whole range of inputs in which modern mechanical and biological technologies are embodied. The proxies for human capital include measures of both the general education level of the rural population and specialized education in the agricultural sciences and technology. General education (measured by the literacy ratio or the school enrollment ratio) is viewed as a measure of the capacity of the population to utilize new technical knowledge. Graduates in the agricultural sciences and technology represents the major source of scientific and technological personnel for agricultural research and extension. The results of the several regressions are summarized in Table 1.

Table 1.
Synthesis of Coefficients From
Intercountry Cross Section Functions, 1960

Labor		.40
Resource Endowments		.35
Land	.10	
Livestock	.25	
Technical Inputs		.25
Fertilizer	.15	
Machinery	.10	
Human Capital		.55
General Education	.40	
Technical Education	.15	
		1.55

The empirical methodology involved the estimation of a function of Cobb-Douglas form using data centered on 1960 for the six variables discussed above. The results, summarized in Table 1, are similar to those obtained in several earlier attempts to measure interstate and intercountry production functions. We depart from earlier interpretations, however, in that the functions which we have estimated are not regarded as conventional neo-classical production functions. Agricultural producers in different countries, in different regions of the same country, and on different farms in the same region are not all on the same micro-production function. This may reflect, in part, differences among producers in their ability to adopt known technology. More importantly, it is also the result of differential diffusion of agricultural technology among regions and countries. And, to an even greater extent, it reflects the differential diffusion of the scientific and technical capacity to invent and develop new mechanical and biological technologies specifically adapted to the factor endowments and prices in a particular country or region.

We consider the common intercountry function which we have estimated as a meta production function. The meta production function is viewed as the envelope of all known and potentially available production "activities". It is only partially available to individual producers in a particular country or agricultural region during any particular historical "epoch". It is, however, potentially available to agricultural scientists. And it is assumed that the invention and diffusion of a new "location specific" agricultural technology through the application of the concepts of physical, biological, and chemical science and of engineering, craft and husbandry skill are capable of making the factor productivities implicit in the meta production function available to producers in less developed countries. It is also assumed that the capacity of a country, or a region, to engage in the necessary research, development and extension is measured by the two proxy variables for human capital. Rapid growth in output and productivity would appear to depend significantly on the ability to make an efficient choice among alternative paths--to choose between placing primary emphasis on releasing the constraints on growth imposed by an inelastic supply of land, through advances in biological technology; or on releasing the constraints on growth imposed by an inelastic supply of labor, through advances in mechanical technology.

The implications of alternative factor endowments on productivity differences and on the alternative paths of technical development are illustrated in Figures 1-3. In Figure 1 the range of partial productivity ratios--output per unit of labor and output per unit of land for the several countries included in the intercountry meta production function estimates are illustrated. In Figure 2 data on the proxy for biological technology (fertilizer input per hectare) and mechanical technology (tractor horsepower per worker) is plotted. Note the close association between the distribution of the individual country observations in Figures 1 and 2. In Figure 3 the time series labor and land productivity paths are traced for a number of developed countries (including Canada).

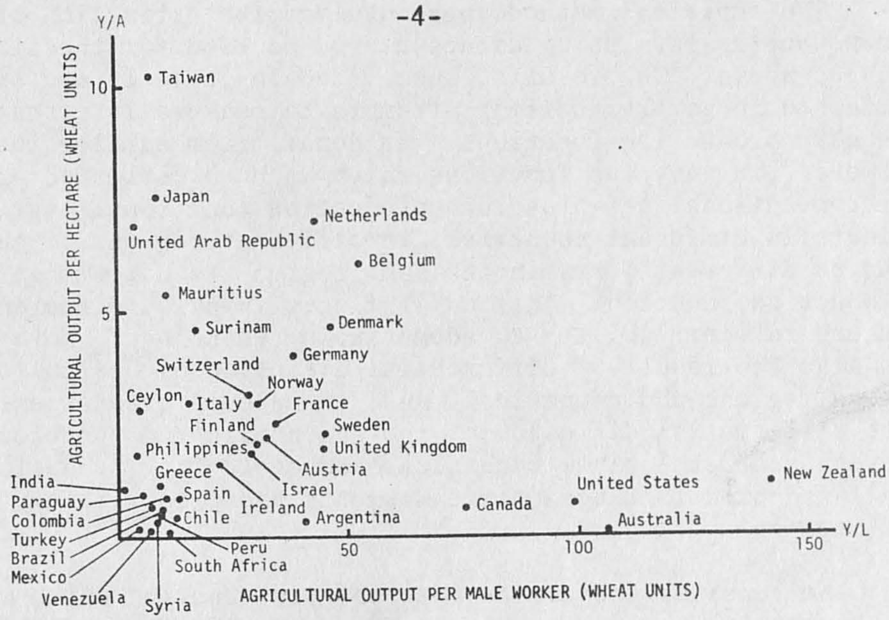

Figure 1. International comparison of agricultural output per male worker and per hectare of agricultural land. Output data are 1957-62 averages; and labor and land data are of year closest to 1960.

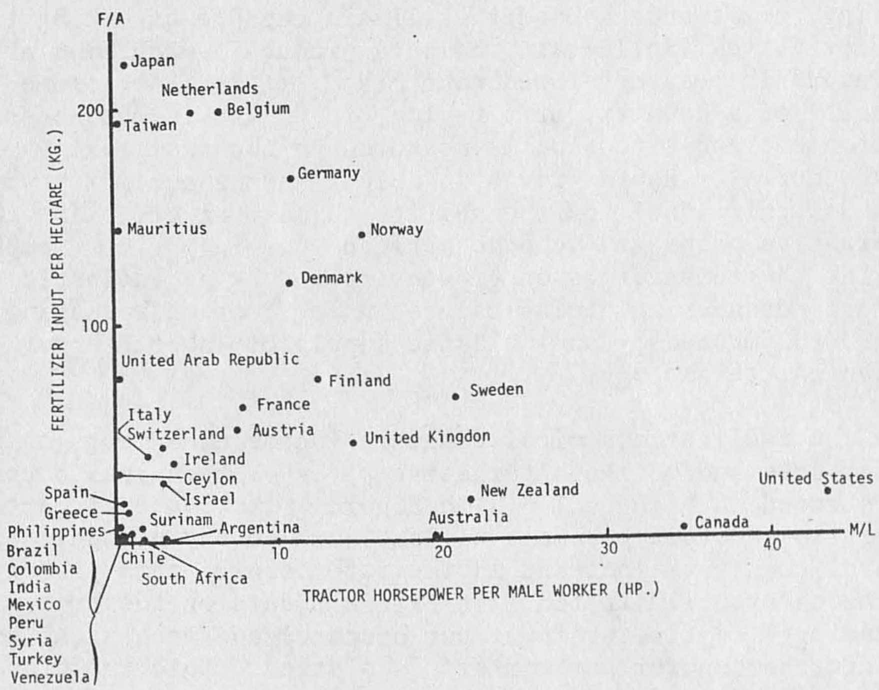

Figure 2. International comparison of tractor horsepower per male worker and of fertilizer input per h hectare of agricultural land. Fertilizer data are 1957-62 averages; and labor, land, and tractor data are of years closest to 1960.

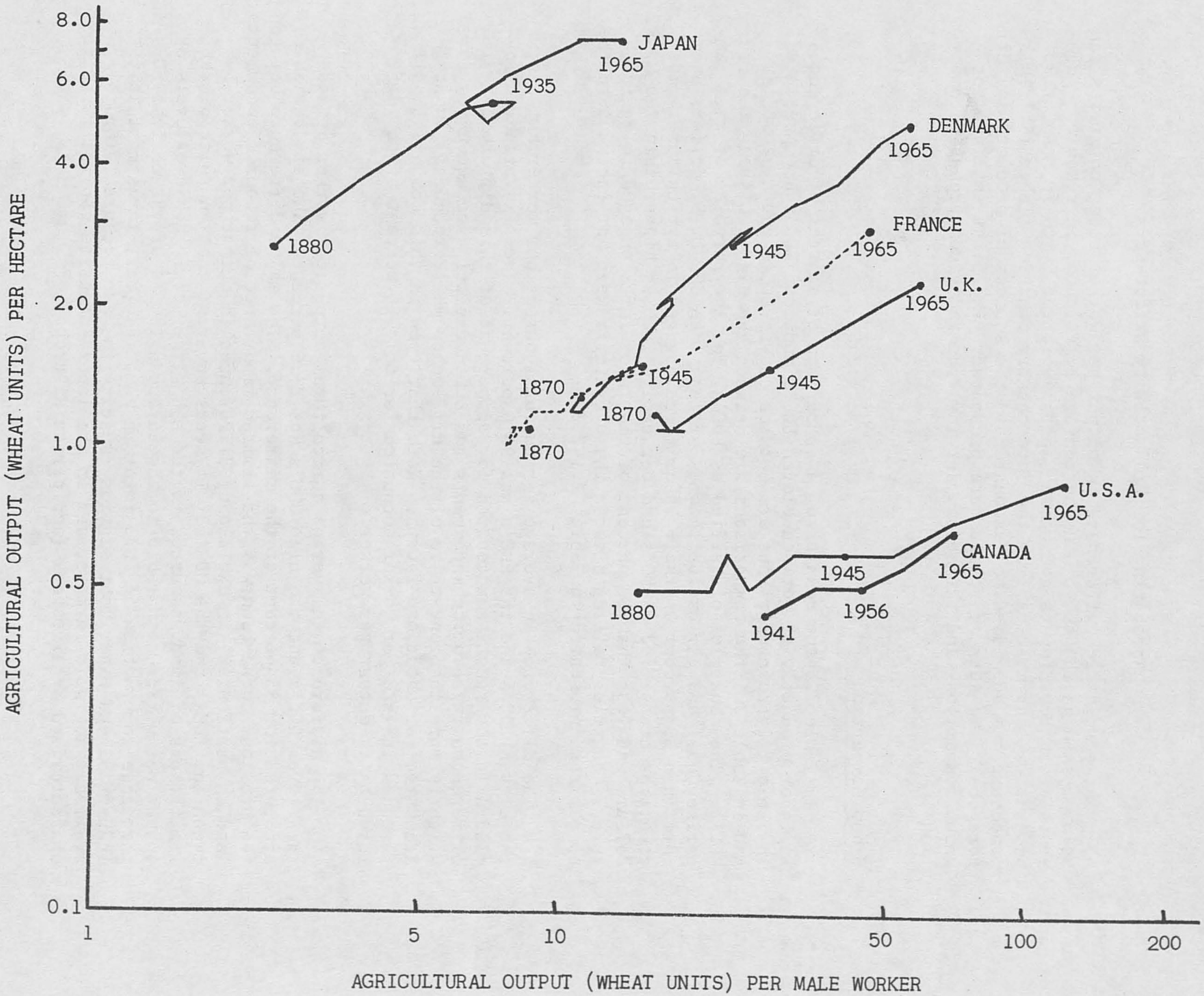

Figure 3. Historical growth paths of agriculture development in the United States and Japan, 1880-1965, and Denmark, France, and the United Kingdom, 1870-1965, and Canada, 1941-1965.

Accounting for Productivity Differences

The percentage differences in output per worker among countries can be expressed as the sum of the percentage differences in resource endowments, technical inputs and human capital weighted by their respective production elasticities from the intercountry function (Table 1). This procedure has been used to "account for" the sources of productivity differences. Two sets of results are presented. The first set involves group comparisons and the second set involves individual country comparisons.

Group Comparisons

In Table 2.1 the results of a comparison of sources of differences in labor productivity between eleven LDC's and four RDC's are presented. In Table 2.2 the comparisons are between eleven LDC's and nine ODC's. And in Table 2.3 the comparisons are between the nine ODC's and the four RDC's. The countries classified as LDC's, for the purposes of this comparison, all had per capita incomes of less than 350 U. S. dollars and more than 35 percent of their labor force engaged in agriculture. The countries classified as DC's had per capita incomes higher than 700 U. S. dollars and less than 30 percent of the labor force engaged in agriculture. Countries falling between these criteria were not included in the comparisons presented in Tables 2.1-2.3.

The difference in average agricultural output per worker between the eleven LDC's and the RDC's was 93.6 percent. The six variables included in the function accounted for 96 percent of this difference. Differences in resource endowments and human capital each accounted for slightly more than one-third of the difference while technical inputs accounted for about one-fourth. Note that even in this comparison differences in land per worker accounted for only 10 percent of the differences in output per worker.

The difference in average agricultural output per worker between the eleven LDC's and the nine ODC's was 83.5 percent. The six variables accounted for 85 percent of the difference. The major difference between the previous comparison was the limited importance of resource endowments, land in particular, in explaining differences in output per worker between the LDC's and the ODC's. It seems apparent that in spite of the limitations of land resources in the LDC's they could achieve levels of output per worker comparable to the European levels of the early 1960's through a combination of investment in human capital, investment in the industrial and experiment station capacity to make technical inputs available to their farmers, and in the labor intensive capital formation characterized by livestock (and perennial crops).

Table 2.1.
Accounting for Differences in Labor Productivity
Between Eleven LDC's and Four RDC's

	Percent		Index	
Difference in Output Per Male Worker		93.6		100
Difference Explained: Total		90.0		96
Resource Endowments		32.6		35
Land	9.7		10	
Livestock	22.9		25	
Technical Inputs		24.5		26
Fertilizer	14.6		16	
Machinery	9.9		10	
Human Capital		32.9		35
General Education	19.5		21	
Technical Education	13.4		14	

LDC's: Brazil, Ceylon, Colombia, India, Mexico, Peru, Philippines, Syria, Taiwan, Turkey, United Arab Republic

RDC's: Australia, Canada, New Zealand, United States

Table 2.2.
Accounting for Differences in Labor Productivity
Between Eleven LDC's and Nine ODC's

	Percent		Index	
Difference in Output Per Male Worker		83.5		100
Difference Explained:				
Total		71.1		85
Resource Endowments		17.5		21
Land	1.8		2	
Livestock	15.7		19	
Technical Inputs		24.3		29
Fertilizer	14.5		17	
Machinery	9.8		12	
Human Capital		29.4		35
General Education	17.6		21	
Technical Education	11.7		14	

LDC's: Brazil, Ceylon, Colombia, India, Mexico, Peru, Philippines, Syria, Taiwan, Turkey, United Arab Republic

ODC's: Belgium, Denmark, France, Germany, Netherlands, Norway, Sweden, Switzerland, United Kingdom

The difference in average agricultural output per worker between the nine ODC's and the four RDC's was 61.5 percent. The six variables accounted for 82 percent of the difference. The results are quite different than in the previous comparisons. Technical inputs and human capital account for only slightly more than one-third of the difference. Resource endowments account for close to half. It appears that output per worker in the ODC's would have great difficulty approaching the levels of the RDC's in the absence of substantial adjustments in labor/resource ratios. It does appear that the ODC's have, in part, neglected the growth that might have been available to them through greater investment in technical manpower and in agricultural science capacity.

Country Comparisons

In Table 3 the results of a comparison of sources of differences in labor productivity between the United States and five individual countries are presented. The individual country comparisons were developed to provide a somewhat more intuitive perspective on the sources of differences in productivity than in the group comparisons.

Japan and India are both countries characterized by a highly labor intensive form of agriculture. In 1960 labor productivity in Japan was several multiples higher than in India but only slightly more than 10 percent of the U. S. Much of the difference in output per worker between Japan and India was accounted for by the level of human capital per worker--the capacity to develop, diffuse, and use resources and technical inputs.

Canada and Argentina are both countries of recent settlement. Labor productivity was relatively high. Resource endowments per worker in Argentina were slightly more favorable than in the United States, and in Canada they were slightly less favorable. In the case of Argentina failure to invest in human capital represents almost as severe a constraint on growth as in India. Use of technical inputs per worker has lagged in Canada. We hypothesize a close interrelationship, in both Canada and Argentina, between underinvestment in human capital and the productivity and use of technical inputs. With appropriate investments in human capital, the development of more productive technical inputs and reasonable economic growth in the rest of the economy, output per worker in both countries should approach that in the United States.

The United Kingdom represents an intermediate situation. Output per worker was slightly higher than in Argentina. Resource endowments clearly represented a constraint on the equalization of labor productivity between the United Kingdom and the countries of recent settlement. However, close to two-thirds of the difference between output per worker in the United States and Great Britain was accounted for by differences in investment in human capital and in the use of technical inputs.

Table 3.
Accounting for Differences in Labor Productivity Between the United States and Selected LDC's and DC's

	India	Japan	United Kingdom	Argentina	Canada
Difference in Output Per Male Worker					
Percent	97.8	89.2	55.8	60.0	24.0
Index	100	100	100	100	100
Difference Explained: Total					
Index	104	74	89	76	98
Resource Endowments					
Index	33	38	33	- 8	20
Technical Inputs					
Index	26	25	24	40	51
Human Capital					
Index	45	10	33	44	28

Conclusions and Implications

The data used in the intercountry productivity comparisons which we have just presented are clearly of uneven quality. The aggregation and index number problems involved in cross country comparisons are nearly insurperable. There are also serious qualifications with respect to econometric method and analysis.

The assumption of independence among the severable factors in the cross country function is, in particular, open to serious questions. It seems reasonable to expect, for example, that there is substantial complementarity between investment in technical education and agriculture and the productivity of the technical inputs available to the farmers of a nation or a region. It also seems apparent that the effect of investment in general education exerts its impact on productivity through its effect on the accumulation and use of resources and technical inputs. If there is one conclusion that we are forced to as a result of this and related work it is the importance of technical education in the agricultural sciences and of schooling and literacy among agricultural producers. Indeed, failure to make such investments represents a major source of low productivity in the use of resources and technical inputs.

The second conclusion to which we are forced by this and related research is that multiple paths of technical change in agriculture are available to a society. The relative endowments of land and labor at the time a nation enters into the development process is important in determining the efficient path in moving toward an optimum position on the meta production function. Failure to chose a path which effectively loosens the constraints imposed by resource endowments can depress the whole process of agricultural and economic development.

The implications of this final conclusion lead us in the direction of an induced development model in which both technical and institutional change are treated as endogenous rather than exogenous to the total development process. In the tests of the induced innovation hypothesis that Yujiro Hayami and I have recently completed it seems clear that in both Japan and the United States the enormous changes in factor proportions and factor productivity has represented a process of dynamic factor substitution, associated with non-neutral changes in the production surface induced by secular changes in factor prices.

The model does, however, remain incomplete. It does not possess formal elegance. It does not adequately explain the feedback process by which public sector research resource allocation has responded to relative factor endowments and factor accumulation. There is, however, the presumption that in the United States, the existence of a decentralized agricultural research system effectively simulated the innovative behavior postulated by the theory of induced innovation.

The model is even more rudimentary in the area of institutional change. It seems consistent with historical experience, to view institutional change as resulting from efforts by economic units (households, firms, bureaus, experiment stations) to internalize the gains and externalize the costs of economic activity and from efforts by society to force economic units to internalize the costs and externalize the gains. In this view the socialization of much of agricultural research, particularly the research leading to advances in biological technology, represents an example of public sector institutional innovation designed to realize for society the potential gains from advances in agricultural technology. The political and legislative history of farm price programs in the U. S. from the mid 1920's to the present can be viewed as a struggle between agricultural producers and society generally regarding the partitioning of the new income streams resulting from technical progress between agricultural producers and consumers.

At present the induced innovation hypothesis, in both its technical and institutional forms, does provide some insight into historical development processes. However, our understanding of the conditions which lead certain nations to move more rapidly than others in creating an institutional environment consistent with an efficient path of technical change remains rudimentary.