INSTITUTO INTERAMERICANO DE COOPERACION PARA LA AGRICULTURA

PROGRAMA DE NACIONES UNIDAS PARA EL DESARROLLO

PROYECTO COOPERATIVO DE INVESTIGACION SOBRE TECNOLOGIA AGROPECUARIA EN AMERICA LATINA
(PROTAAL)

COMMENTS ON "AN INDUCED INNOVATION INTERPRETATION OF TECHNICAL CHANGE IN AGRICULTURE IN DEVELOPED COUNTRIES" PRESENTED BY V. W. RUTTAN

John K. Lynam

Documento preparado para presentarse en el Seminario: "Cambio Técnico en el Agro Latinoamericano: Situación y Perspectivas en la Década de 1980", organizado por el IICA/PNUD, que se llevará a cabo los días 1, 2 y 3 de setiembre de 1981 en Coronado, Costa Rica.

Costa Rica, 1981

000028[illegible]

[redacted]

Comments on: "An Induced Innovation Interpretation of Technical Change in Agriculture in Developed Countries" 1/

John K. Lynam*
Agust 1981

The theory of induced innovation conceivies of technical change as arising out of and being responsive to market forces and is thus seen as being endogenous to the economic system. The theory thus provides an efficiency standard against which technical change can be evaluated, in terms of both the factor bias of technology and the allocation of research resources. My comments shall be directed toward the theme of this conference, under which I wish to explore the applicability of the induced innovation theory to technical change in Latin American agriculture. By applicability I wish to analyze three principal issues, the validity of the theory, its explanatory power when applied to Latin American conditions, and the policy recommendations which arise from the theory.

---

* The author is agricultural economist in the cassava program, Centro Internacional de Agricultura Tropical (CIAT), Cali, Colombia.

1/ Paper presented by Vernon W. Ruttan at the Conference of The Cooperative Research Project on Agricultural Technology in Latin America (PROTAAL), IICA, San Jose, Costa Rica. September 1-3, 1981.

In discussin the validity of the theory a distinction should be made in the basis on which validity is being assessed. One basis, as was done in Dr. Ruttan's paper, is to test the conclusions of the theory against the empirical record. The other basis is to establish the validity of the assumptions on which the theory is based. If the assumptions in certain situations do not hold, the explanatory power of the theory is obviously circumscribed. However, the theory has not been invalidated; only the conditions under which it is operative has been restricted. Nevertheless, the theory still provides a reference standard in terms of market efficiency against which technical change under these non-operative conditions can be evaluated and which therefore allows the theory to have potential policy implications. My

comments will focus on the applicability of the assumptions of the model in Latin American agriculture and in the process I will attempt to develop a framework for assessing which market factors are operative in influencing technical change.

Changes in relative factor prices are in large part the engine of the induced innovation theory. The theory asserts that biases in technical change are responsive to changes in relative factor prices, which in turn directly reflect relative factor scarcities at both the social level and the farm level. The correspondence between aggregate factor proportions in the economy and internal factor proportions to the farm is critical to the theory and therefore implicit to the theory is the assumption of a relatively homogeneous farm size distribution, an assumption which obviously does not apply to Latin America.

A skewed distribution of land and labor causes two problems in the theory. First, there is a duality in farmer response to factor prices reflected in the fact that marginal products of factors differ across farm sizes and secondly, technical possibilities are differentially profitable across farm sizes. Thus, in Latin America the bulk of the agricultural labor is found in the small farm sector where production is highly labor intensive. In the small farm sector the marginal value product of labor is low and may be below the wage rate as family labor is applied in accordance to

average product rather than marginal product. These farms nevertheless usually have a high seasonal demand for labor and in may cases are major employers of wage labor. Such farms tend to cultivate a high percentage of their farm area and to cultivate it more intensively using multiple or associated cropping and as well tend to select a labor-intensive product-mix.

On large scale farms, on the other hand, the marginal product of labor is generally well above the wage rate, principally because the real cost of labor to these farmers incorporate high organizational costs of managing large labor forces. Moreover, labor demand has seasonal peaks which, where they correspond to peaks in the small farm sector, make labor substantially more expensive due to both the time and organizational costs in assembling a work force and because small farm family labor will have a high opportunity cost.

A type of duality thus exists in the labor market, which is reinforced by friction in the land market. This friction is due to the fact that small lots tend to be more expensive, there is differential access to credit on the part of large and small farmers, farms tend to be sold as units rather than parcels, and there are institutional risks in renting land to tenants. Moreover, land is a secure store of wealth as well as embodying certain political influence, which substantially reduces the incentives to sell the land for short-term profits.

Given the internal factor proportions of the farm large farms tend to cultivate only a portion of their land, leaving the rest in fallow or pasture [2/].

Market prices for factors thus reflect forces acting at the relative extremes of the farm size distribution rather than average relative factor endowments in the economy. The result is underemployment of both land and labor resources in the agricultural economy and although these markets have thus been characterized as distorted or imperfect, the fact remains that these markets function as efficiently as is possible given the distribution of resources in the sector and the rational behavior that arises out of that distribution. In terms of the induced innovation theory then factor prices have little correspondence to average factor endowments in the economy.

The crux of the theory, however, revolves around whether technical change is responsive to changes in factor prices, even though in a Latin American context the factor price linkage of technological bias to relative factor scarcity in the economy is weak. Nevertheless, the argument may be extended to conclude that technical change in Latin American agriculture is not very responsive to changes in land/labor

---

2/ For a more extensive discussion of these issues see Berry, R.A. and W.R. Cline, "Agrarian Structure and Productivity in Developing Countries, Baltimore: John Hopkins University Press, 1979, pp.5-30.

price ratios. Why ? In a very skewed farm size distribution factor bias in technical change corresponds very closely with scale bias. Thus, in most Latin American countries the agricultural labor force continues to grow absolutely and most of this growth is being absorbed in the small farm sector. Given that access to land in the small farm sector does not increase, this would imply downward pressure on wages. The theory would suggest an induced bias toward land saving technology and as a result, a bias toward small scale farms. However, over a wide range of labor prices, labor-saving technology is still the principal cost-reducing technology for large scale farmers.

The critical point is that factor price shifts over quite wide ranges do not change the underlying demand for technology bias, which is instead determined by technical possibilities given by farm size. That is, large and small scale farms operate on completely different isoquants in factor space, each having limited factor substitution possibilities. As well each scale farm faces different opportunity costs of factors. Changes in market factor prices affect comparative advantage between large and small scale farms but do not substantially alter the underlying demand for technology bias on the part of the different scale farms. Models of technical change in Latin American agriculture have thus focused on how differences in demand for new tech-

nology on the part of different scale farmers is translated into supply of new technology [3/]

The induced innovation theory states that it is prices that guide research resource allocation decisions in the translation of demand into supply of new technology, even if these prices are in a sense distorted. Thus, do the micro-foundations of the theory still hold, even if the process is inefficient ? Moreover, it is at the microeconomic that the validity of the underlying assumptions of the theory can be most adequately assessed.

The microeconomics of the induced innovation theory are based on the conception of an innovating firm whose activities are defined by three principal constructions:

1) the firm is involved in both research and production activities, the research activities lowering the costs of production of the firm;
2) innovating firms face an innovation possibility curve defined in factor space where each research activity on the curve alters the production process in varying factor-saving directions and where each process is defined as having a relatively small elasticity of factor substitution; and

---

3/ Piñeiro, M. et.al. "Technical Change in Latin American Agriculture: A Conceptual Framework for its Interpretation," Food Policy, 1979(4): 169-177.

3) the profit maximizing firm faces relative factor prices which reflect relative factor endowments in the economy.

Benefits to innovation are evaluated in terms of the reduction in costs of production from present levels minus the research costs. Benefits are thus captured by the innovating firm in terms of lower production costs. The behaviorial decision is therefor to choose the research activity which maximizes benefits, the decision being cast as an investment decision.

The issue then is to what extent these assumptions capture technical change in agriculture in general and whether these then extend to the particular case of Latin American agriculture. Particularly, how does agricultural research depart from the conception of an innovating firm facing a well-defined innovation possibility curve from which it chooses an optimum research portfolio.

Agricultural production is characterized by an atomistic production structure in which the firms have neither the incentives nor the capital resources to invest in research. Technical change in agriculture is in general embodied in the inputs purchased by farmers and research is thus done by the input supplying firms. Technical change is thus characterized by an adoption decision and a decision about choice of research portfolio. The two decisions are obviously related in that

the farmer will adopt that technology which will most reduce production costs. However, will the research done by the supply firms be based on cost minimization at the farm level?

In terms of conceptualizing technical change in agriculture in terms of the induced innovation theory there is a tendency to abstract away from the different economic actors and to invest a single entity with the decision problem of allocation of research resources that maximizes benefits. However, the choice of research activity by the input supply firm is not based directly on cost reduction in the production of agricultural goods but rather on increasing the input share. This separation of economic behaviour would not be critical if each input firm faced the same innovation possibility curve. Farmers would adopt that innovation which most reduced farm level costs. Such cost reduction is obviously directly linked to factor prices, and the supply firm would choose that technology which minimized farm-level cost in order to maximize sales of the inputs.

However, different types of input supply firms, that is, for example, tractor firms versus hybrid seed firms, operate along different portions of the innovation possibility curve. While competition within each type of supply firm should guarantee the research activity that results in the lowest cost at the farmer level, this does not necessarily hold for research done by different types of input firms. Thus,

research choices between different types of input supply firms are in a sense competitive and again raise the specter of Salter's criticism that research lines would be followed as long as they reduced farm level costs, thus creating a demand for their input.

In Latin American agriculture much of technical change, since it is embodied in inputs, can be reduced to a choice-of-technique problem, with the choice of technology being as responsive to average farm size as to changes in relative factor prices. A principal issue in technical change in Latin America is the choice between technology transfer and research investment to develop technologies appropriate to Latin American conditions. Here again a factor bias linked to a scale bias is inherent in the decision (Table 1). Particularly, labor-saving technology is in general directly transferable or transferable with minimal adaptive research through multinational input supply firms. Land-saving technology, on the other hand, tends to be environmentally sensitive which is most cases requires an indigenous research capacity. Moreover, the benefits of research on land-saving technology is not easily captured by the input supply firm and thus tends to be located in the public sector. Research on land-saving technology is thus even further removed from market forces [4/].

4/ In particular, only satisficing behavior can be said to apply to public research in the sense that research lines must reduce costs at the farm level, i.e. be adoptable; however, there is no behavioral mechanism that guarantees that there is a search for maximum cost reduction.

Institutional efficiency is then critical in explaining technical change in Latin American agriculture and in particular the issue arises as to the effectiveness of public agricultural research institutes in developing essentially land-saving technologies, when the principal demand for these technologies comes from the small-scale farm sector. To policy makers who control the funding of such activities, a comparison between the costs and returns of direct transfer of mechanical technology and the costs of maintaining an extensive agricultural research capability becomes important when there is competing demands on limited budgetary resources. Apart from any political biases that may be brought to bear, governments have the option of fostering technical change for which a large investment in agricultural research is not necessary.

In summary, the central role of factor prices underlying the induced innovation theory becomes ineffective in a Latin American context. At the macro-level factor prices do not necessarily reflect relative factor endowments in the economy. Moreover, factor prices are dominated by internal factor proportions to the farm in influencing demand for technology and therefore are an inefficient means guiding technical change in the economy. This conclusion extends to the micro-level where the behaviorial assumptions guiding research allocation are best described as satisficing behavior, in

that the guiding rule is that technology reduce costs at the farm level but not necessarily maximize cost reduction. Again cost reduction will depend principally on the internal factor proportions of the farm. How different demands for technology get translated into supplies remains undefined, except that there is a distinct bias toward large-scale farmers due to the ease of directly transfering labor-saving technology from the developed countries and that small-scale farmers are neceessarily reliant on public agricultural research.

A neoclassical model of technical change in Latin American agriculture must, therefore, encompass the substantial heterogenity of farm sizes and the wide distribution of internal factor prices. A more appropriate conceptualization would be to assume that individual farms produce with fixed-proportion techniques or techniques with very limited substitutability. The choice set in the search for cost-reducing technology would vary by farm size, resulting in expansion paths along different factor ratio rays. However, it would be highly unlikely that expansion along these rays would be at the same rate such that each farm size would produce at the same unit cost. But, this seeming contradiction highlights the other feature of Latin American agriculture, which is crop specialization by farm size [5/]. Different size farms thus face

---

5/ Specialization arises out of different factor intensities in production across crops, size and integration of regional markets and access to market, riskiness in the production process, and ecological specificity.

different unit cost lines.

The model would then seek to explain a differential rate and bias in technical change between large and small scale farmers and the impact of this on production and factor use in the economy. The mechanism driving the model would be changes in demand conditions for large and small farm crops, labor growth in the small farm sector, and capital price changes in the economy, all of which would in turns determine comparative advantage between different farm strata. However, there is no necessary endogenous determination of bias in technical change unless the small and large farmers compete in the same product markets. This then forces the model to incorporate institutional and economic policy biases.

Induced Innovation and Economic Policy in Latin America:

Having suggested why the induced innovation mechanism is ineffective in Latin America, what does the induced innovation theory imply for a policy toward technical change in Latin America. As Dr. Ruttan has suggested, the theory argues strongly for "institutional changes that lead to a convergence of market and efficiency prices." However, in Latin America it has been argued that either market or efficiency prices for land and labor that hold the resource distribution constant, firstly, are poor indicators of aggregate resource scarcities in the economy and, secondly, are ineffective means of allocating these resources in the agri-

cultural sector. The theory would therefore point to a redistribution of factors to make technical change both more responsive to price change and therefore more efficient. However, the history of land reform in Latin America would suggest that the institutional innovations necessary to significantly alter land distribution are severely constrained by the congruence of political resources and land ownership patterns. The design of technology will therefore have to continue to be made in an environment characterized by a skewed distribution of land and labor resources.

Nevertheless, while technical change in Latin American agriculture is not very sensitive to factor price changes, technology adoption and to a more limited extent research resource allocation is heavily influenced by relative prices of inputs and outputs. Several studies in Latin America have shown tractor demand to be a very responsive to tractor prices, particularly in relation to mechanizable crop prices[6/] Because of the ease of technology transfer, technical change involving labor-saving technology directed toward large scale commercial cropping can be generated by government price policy. Crop research while potentially complementary to commercialiazation of large scale farms, is critically necessary to any technical change in the farm scale sector. The

---

6/ Sanders, J.H. and V.W. Ruttan. "Biased Choice of Technology in Brazilian Agriculture", in H. Binswanger and V.W. Ruttan, Induced Innovation, Baltimore: John Hopkins University Press, 1978, p.276-296.

public sector thus has and continues to play a central role in guiding technical change in Latin American agriculture. Thus, agricultural research investment (or underinvestment) becomes a key policy instrument in a Latin American context.

The policy implications of the induced innovation theory are in a sense turned on their head, in that it is proper design of agricultural technology and policies that are necessary to induce in a dialectical fashion the type of structural changes necessary for innovation to be guided by the price mechanism. The key element in such a policy is an effective public system of agricultural research and extension linked to an independent agricultural planning office. Planning agricultural research in relation to policy objectives is a complex undertaking, but essential to achieving balanced growth in Latin American economies, that is growth that contributes to employment and improved nutrition as well as increased production. This linkage between policy objectives and technical change can be sketched in terms of three possible scenarios.

The most optimistic strategy for technical change would be the design of technologies that would precipitate structural change, principally through making extensive production activities unprofitable, generating diseconomies of large scale production, and spawning a land rental market 7/.

7/ De Janvry suggests such a possibility for Argentine agriculture but does not specify what type of technology would precipitate such change.

A technology that would give a substantial comparative advantage to beef production on the frontier combined with a highly profitable technology for small to medium-scale farmers in the 10 to 50 ha. range could possibly pricipitate such change given appropriate policies such as land taxes and discriminating credit schemes designed to free up factor markets. The design of such a strategy, however, requires a very firm understanding of the agricultural sector, including institutional linkages and adjustment in factor and commodity markets. Such a policy, moreover, would then call into play the mechanisms essential for induced innovation to take hold.

What could be called the line-of-least-resistance strategy would focus policies and technical change on commercializing large-scale agriculture. Subsidies have in general been necessary in such a case. The probable result is an agricultural sector with a high cost structure and the diseconomies of large-scale migration of labor into the urban sector. Such a policy is shortsighted but completely compatible with institutional biases both in the agricultural and industrial sector.

A third potential strategy is essentially a hybrid of the other two and argues for simultaneous development of large-scale and small-scale agriculture free from subsidy intervention. Technology design revolves around maintenance

and strengthening of crop specialization by farm size so as not to generate a product treadmill between farm sizes. Design as well takes into account internal factor proportions to the farm, mechanical and chemical input prices, and output prices. Output prices are particularly problematic in the case of small-scale agriculture. In general, small farmers in Latin America produce crops with either very low demand elasticities or very limited markets 8/. Benefits of new technology in general are captured by consumers. Large scale farmers generally produce export crops or crops with high elasticities of demand and benefits are internalized by the producers 9/. The implications of a product treadmill are obviously very different from a land treadmill. New technology for small farmers may thus be counter-productive unless price floors or price supports are introduced or high-demand elasticity crops are developed for small farmers. To be effective the strategy depends on careful planning in agricultural research, its translation into appropriate technology, and development of institutional and policy linkages.

8/ This does not apply to coffee grown outside Brazil. Labor intensity of the crop and the mountainous terrain give an advantage to smaller scale farmers.

9/ Institutional biases provide one rationale for such a crop distribution. For discussion of such biases in a Marxian framework see L. Crouch and A. de Janvry, "The Class Basis of Agricultural Growth", Food Policy, 1980(5): p. 3-13.

In summary, a model of technical change of Latin American agriculture cannot abstract away from the very skewed distribution of factors in the sector and the very rational economic behavior that underlies this farm size distribution. What I would see as some of the technical, economic and behaviorial determinants of such a theory have been sketched here. The analysis points to technical change as a key factor in influencing more productive use of unemployed land and labor resources in the sector, growth in agricultural production, and changes in the distribution of rural income, with the associated impact that income distribution has on nutrition, rural-urban migration, and economy-wide unemployment. Research resource allocation and technology design become key policy variables in Latin American agriculture, with their effectiveness being principally dependent on unbiased institutions. Incorporation of institutional and political linkages in a model of technical change is necessary but analysis of the determinants of institutional bias must isolate means by which these biases can be overcome. A fully deterministic model of institutional, economic, and technical change in a sense becomes and end in itself. The more relevant issue is in having understood the structural constraints that make the induced innovation mechanism inoperative and the institutional biases that arise out of those constraints, what are the criteria and strategies that lead to more effective and responsive institutions and in particular, agricultural research systems.

Table 1. Characteristics of Different Types of Agricultural Technology.

Technology	Embodied Imput	Tendency of Factor Saving Bias	Transferability	Crop Specificity
Mechanical	Tractors and Implements	Labor	Directly Transferable	Low
	Harvesters	Labor	Directly Transferable	Medium
Chemical	Fertilizer	Land	Adaptive Research	Medium
	Pesticides	-	Adaptive Research	Medium
	Herbicides	Labor	Adaptive Research	Medium
Biological	Seeds	Land	Environmentally Sensitive	High
Agronomic	Management Information	Land	Environmentally Sensitive	High

FECHA DE DEVOLUCION