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MECHANICAL TECHNOLOGY IN EGYPTIAN, INDIAN AND PAKISTANI AGRICULTURE: OBSERVATIONS FROM AN "INDUCED INNOVATION" PERSPECTIVE

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MECHANICAL TECHNOLOGY IN EGYPTIAN, INDIAN AND PAKISTANI AGRICULTURE: OBSERVATIONS FROM AN "INDUCED INNOVATION" PERSPECTIVE

Introduction

Much recent work on agricultural development has been devoted to shedding light on the mechanisms by which improved agricultural technology is generated and diffused. Earlier studies of the sources of growth identified the need for a constant stream of innovations responsive to the farm environment as the basis for sustained growth in the rural sector.[1] But the discussion of the means by which "markets" emerge or "feedback loops" between demanders and suppliers of technology are created, was descriptive rather than analytical.

Currently, most efforts to reconstruct the past and to suggest policy options for the future, embed the process of technology generation in some kind of "induced innovation" framework.[2] In its simplest form, this argument suggests that, like many other activities, research and the development of new technology is driven by economic scarcity. In the most straight forward case, innovative activity leads directly to technology that aguments scarce factors in one way or another. In its extended form, the argument also suggests that the development of various institutions, including those concerned with research, are driven by the same forces.

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[1] Classic examples, as relevant as when they were first published, are T.W. Schultz, Transforming Traditional Agriculture, Yale University Press, 1964, and Arthur Mosher, Getting Agriculture Moving, Agricultural Development Council, 1965

[2] Although the literature on induced innovation is by now quite large, seminal ideas are to be found in Haymaii and Ruttan, Agricultural Development: An International Perspective, Johns Hopkins Press, (Baltimore), 1971, and Binswanger, et al., Induced Innovations: Technology, Institutions and Development, Johns Hopkins Press, (Baltimore), 1978.

The framework is explicitly dynamic. Each new technology that is developed contains, as a result of its subsequent interaction with such structural characteristics of the rural sector as farm size, tenure arrangements, markets, etc., the demand for a new round of innovation. Releasing one set of constraints in a production systems produces, in addition to greater output, a new set of limits to exploiting the available resources.

The interaction that produces a dynamic environment for technological change takes place in two types of "markets." In one, the actors are private entreprenuers with the conventional motives of profit. Farmers, interested in agumenting or improving the efficiency with which they use scarce resources, are assumed to search for ways of doing so. Similarly, firms with the capacity to produce technology, seek to develop innovations that will be rewarded by sales in the marketplace.

A second "market" involves public sector institutions. Here too farmers may search for technology and the various organizations who are potential suppliers, may seek "profits." But both demanders and suppliers have political and bureaucratic intermediaries whose objectives become a part of the decision environment. The result is a much more complex system whose workings require political as well as economic interpretation.

Because of the complexity of the issues involved, much of the work relating social organization to the efficiency of the markets for innovation has been centered on the historical experience of particular countries. Cross-country comparisons at similar stages of development or similar points in time run the serious risk of spurious conclusions because of confounding environmental factors. The following essay is no exception to this rule, but because of the similar agro-climatic environment of the areas being investigated, there is at least a presumption that the technical determinants of the demand for mechanical innovations may have a number of similarities. If the indirect effects of government price and income policies can then be identified and accounted for on the demand side, comparing similar agricultural environments would permit a clarification of the role that the supply side of innovation markets have played in the mechanization process.

A Systems View of Induced Innovation

The multiple, often interweaving strands of thought that characterize the recent literature on innovation suggest the desirability of adopting an explicit "systems" image of the process. Figure 1, based on de Janvry's 1977 formulation, has proved to be a useful framework for the systematic exploration of both the supply and demand for agricultural innovations.[3]

Figure 1 is limited to the variables and linkages for technology demand and supply in which there are no transactions across national boundaries.[4] The framework incorporates social, political and institutional actors, as well as those economic and engineering considerations that have traditionally been the subject of investigations of technological change. Thus the framework accommodates both the "radical" view of technological change which stresses the role of social, political and institutional elements in deter-

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[3] Alain de Janvry, "Inducement of Technological and Institutional Innovations: An Interpretive Framework" in <u>Resource Allocation and Productivity in National and International Research</u>, T.M. Arndt, ed., University of Minnesota Press, Minneapolis, 1977.

[4] For a discussion of a "two-country" model using a similar diagram, see Carl H. Gotsch and Norman McEachron, "The Choice of Agricultural Technology in Developing Countries," in <u>Internal and External Constraints on Technological Choice in Developing Countries</u>, National Science Foundation, Tycooly International Press, 1983. Some reference to an "open" systems model is needed to explain the influx of tractors in all three countries.

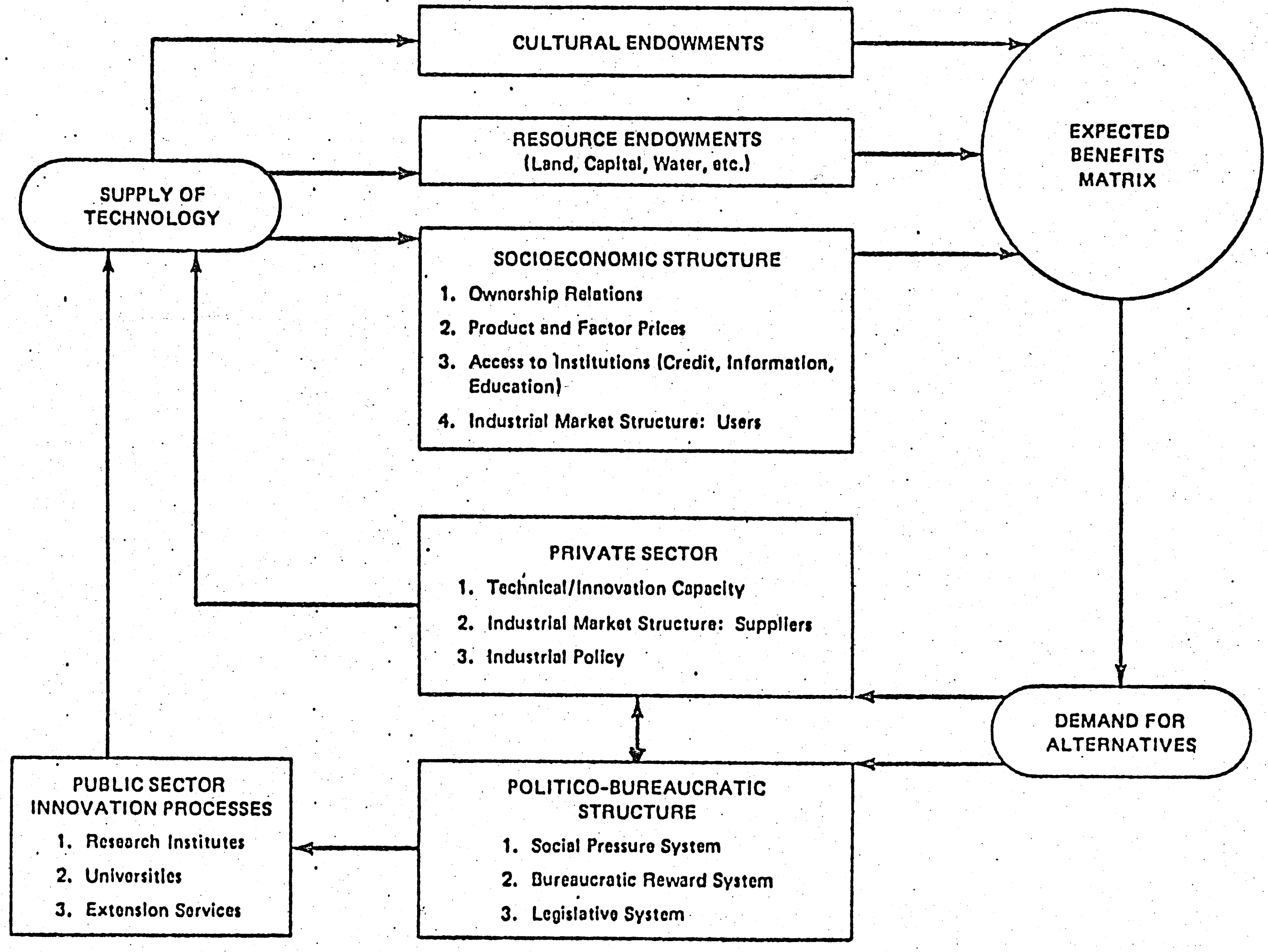

Figure 1. SUPPLY AND DEMAND FOR TECHNOLOGICAL ALTERNATIVES IN A CLOSED SYSTEM

mining the patterns of innovation and diffusion, as well as the more neo-classical view which sees the wellsprings of change in relative factor scarities.

The Expected Benefits or Demand Matrix: The starting point in developing empirical material relevant to the formulation in Figure 1, is the *ex ante* benefits matrix. (In de Janvry's formulation, the "pay-off" matrix.) This matrix describes the gains and losses that various groups expect to receive from an investment in technology. In the applications of subsequent sections, the alternatives being considered are embedded in physical capital, but the idea can be broadened to include various organizational and institutional innovations that affect the benefits and costs of a technology (e.g., hire-service markets, access to credit and information, agricultural research and extension systems, etc.).

The idea of a benefits matrix and its implicit or "latent" signals regarding the value of new technology can be made concrete, albeit narrowly interpreted, by thinking of typical, farm level linear programming models in which factor endowments, commodity prices and technological coefficients have been developed from micro data.[5] Solutions to the constrained profit maximization problem for representative firm provides not only estimates of the optimal levels of the decision variables, e.g., the amount of land and water to be devoted to different crops, but simultaneously produces an estimate of the economic value to the firm of either (1) augmenting scarce

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5 For a broader discussion of the de Janvry farmework and the interactions between various components of the agricultural research "system", see Vernon Ruttan, *Agricultural Research Policy*, University of Minnesota Press, Minneapolis, 1982, Chaper 3. deJanvry uses the word "latent" to indicate that the benefits associated with the augmentation of scarce resources do not necessarily constitute effective demand.

resources, or (2) altering the technical parameters of the activities that profitable but constrained by scarce resources. These imputed scarcity values ("shadow prices") constitute the incentives that spur entreprenuers to seek technologies not currently in the available choice set.

The conceptual framework of mathematical programming also immediately makes clear that innovations induced by relative scarcity implies nothing about social optimality. It is true that the values of domestic resources reflect the technical relationships and factor endowments of the agro-climatic environment, but shadow prices are also determined by the prices of inputs and outputs. To the extent that these are distorted by restrictive trade and commodity policies or by institutional non-market regulation of macro variables such as wages, interest rates and foreign exchange rates, the signals from the benefits matrix will not be socially efficient.

Technology Supply Response: Figure 1 shows two channels, private and public, that are potential responders to the signals coming from the demand side. As a number of wrtiers have pointed out, the two channels or "markets" are by no means substitutes for one another.[6] The private sector can be expected to focus on those innovations whose research costs can be most readily recovered. The development of mechanical technology is an obvious

[6] For a highly readable discussion of the debate over the division of labor between public and private institutions, see Vernon Ruttan, "Changing Role of Public and Private Sectors in Agricultural Research," Science, Vol 216, April, 1982. Some issues, such as mechanization and varietal improvement, are relatively straight forward. Ruttan also notes, however, that the cost of developing pesticides that are desirable from an environmental (social) point of view, may exceed private benefits.

example. New varieties, on the other hand, are more problematic. If a new seed is produced that can subseqently be harvested by farmers and used again or sold to neighbors without penalty, it will be difficult to recover the considerable costs that the breeding work incurred. In mixed economies, public sector agencies exist to deal with the range of public problems on which research would be desirable, but for which private gain is insufficient to cover social costs.

The rules of thumb governing what one might find in the public and private spectors respectively, are not hard and fast and can change over time. When hybridization made it possible to capture the benefits of private investment in plant breeding, many seed companies took advantage of the technology to develop their own products. In the area of pesticides, the reverse has occurred. The original agents such as DDT and the organophosphates could be protected by patent and were broad-spectrum materials that could be profitably marketed to a wide variety of consumers. As environmental controls became more stringent and pest resistance to such materials increased, the required chemicals became (a) more specific, and (b) more costly to shepherd through the regulatory procedures. The National Academy of Sciences study on the subject notes with considerable concern the resulting impact on public welfare of the lack of private incentives.[7]

The determinants of technology provided by the public-sector involve a much more complicated set of objectives than those governing private businesses. For example, the ability of different social and political

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7 National Academy of Sciences, Pest Control Strategies: An Assessment of Present and Alternative Technologies: Report of the Executive Committee, Washington, D.C. 1975.

groups to make their influence felt is an important ingredient in the way research resources are allocated. Indeed, differences in the ability of interest groups to affect the role of public sector organizations has, in recent years, actually made the normally sacrosanct U.S. agricultural research establishment controversial.[8]

There is undoubtedly a good deal of truth in the charge that politicians and bureaucrats have considered the research needs of large farmers more favorably than the needs of small farmers or landless laborers. This is simply a reality of life in political sytems which permit substantial wealth and income disparities to exist. Large farmers speak for, and are often one, with the political establishment.

What commentators often conveniently forget, however, is that the majority of the research funds involve the development of technology that is not scale dependent. Without it, no increases in the productivity and incomes of small farmers would be possible.

Public sector organizations in developing countries frequently act as a conduit in the diffusion of technology because of their strong links to the international research community. Because they are not profit seeking, they are theoretically in a position to provide an institutional mechanism for screening or adapting technology to suit local needs. However, their

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8. The book on this theme with the catchiest title is the Nader inspired Hard Tomatoes, Hard Times. The reference is to the tomato varieties that were developed to facilitate mechanical harvesting. (James Hightower, Hard Tomatoes, Hard Times, Shenkman Publishing Company, Cambridge, MA, 1973). Perhaps more significant has been the class action suit brought against the University of California by the California Rural Legal Assistance group on behalf of the State's "small farmers." The charge is not only that public funds have been used inappropriately, but that a conflict of interest exists when members of the Faculty of Agriculture sit as directors of large agri-business firms. (A. Meyerhoff, "Big Farming's Angry Harvest," Newsweek, March 3, 1980).

performance in this area has not been particularly satisfying. The roots of the failure to screen technology adequately are same conditions that result in research that has little relevance for local problems, namely, the lack of any real linkages between government organizations and the potential indigenous users. Unlike the private sector, where the linkage must be established or the suppliers will not survive financially, it is possible for government and government sponsored agencies to pursue topics that have little redeeming social value for long periods of time. Where research topics are driven by individual motivations, e.g., academic interests or the desire to emmulate work being done in developed countries that can afford basic research, there is nothing to guarantee that these findings will be socially desirable.[9]

The Socio-Economic Screen: The final step of the conceptual systems framework involves reintroducing the supply of technology and institutional alternatives that emerge between time t-1 and time t into the demand model.

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[9] Blackledge, after visiting some 50 industrial research centers in 13 developing countries, concluded that an overwhelming amount of the work was not relevant to the immediate and medium term problems faced by the manufacturing sector of the countries in which they were located. J. Blackledge, "The Role of the Research Institute in Industrial Growth," mimeographed, Denver Research Institute, Denver, Colorado, 1972.

In a similar vein, in one of the few in-depth studies of scientific communities in developing countries, McCarthy discovered that scientists located at regional universities in the Philippines were more likely to engage in research with a Philippine focus. These scientist were relatively isolated from the international scientific communtiy and instead had contact with local industries, large farmers and professional and community groups. F. McCarthy, "The Cultural Networks of Philippine Social Scientists," Unpublished Ph.D. Dissertation, University of Michigan, Ann Arbor, Michigan, 1972

To do this, the alternatives that have been generated by various research and diffusion activities must first be filtered through the existing economic and micro institutional structure. Only then will the impact on the industrial or agricultural community of a particular locale become visible.

A major structural "screen" is the relationship between technology and firm size or output. A key to this relationship is the divisibility (or economies of scale) of the technology. For technologies that are divisible, firm size is not a long-run barrier to adoption (e.g., improved seeds and fertilizer in agriculture). A highly indivisible technology with substantial economies of scale, on the other hand, obviously favors larger firm size. Where the technology is such that a stream of services cannot be provided to small size firms through hire services markets or institutional innovations such as cooperatives, the socio-economic screen may result in undesirable distributive effects.

There is now considerable evidence that, at least in agriculture, if the innovation is highly divisible (e.g., improved seeds and fertilizer), farm size is not a barrier to adoption. There may admittedly be a lag of several years between the adoption by large progressive farmers and subsequent use by their smaller neighbors but even in the face of credit constraints, the actual benefits matrix that describes what various social groups have achieved bears a close resemblance to the<u>ex ante</u> matrix that describes what they could achieve.

Evidence concerning the impact of the socio-economic screen on the diffusion of mechanical technology, as opposed to biological and chemical innovations, is somewhat less encouraging. Indivisibility is a common phenomenon and not always subject to the development of hire-service markets. In the case of tractors, of course, their mobility and alternative use as transportation vehicles has caused tractor service markets to develop rather quickly in most developing countries. On the other hand, the markets for water--a crucial production input in arid and semi-arid agriculture--are less advanced. Tubewells, low-lift pumps and motors cannot be easily moved and consequently the hire-service arrangements that transform a stock of technology into a flow of services have often been slow to make their appearance.

The Demand for Agricultural Mechanization in Egypt, India and Pakistan

Agro-Climatic Environment: To students of intensive irrigated agriculture in the arid portions of northwest India and northeast Pakistan, the outlines of Egyptian agriculture is generally familiar.[10] Many of the crops are similar. Cotton and rice are the major cash crops in summer; berseem (Egyptian clover), the dominant animal fodder, competes with wheat for land in winter and with long staple cotton in spring. Planting and harvesting in May-June and October-November are periods of feverish agricultural activity that tax both man and beast.

Even with increasing mechanization, livestock continues to play a role

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[10] The areas referred to as "India" and "Pakistan" are represented by the arid, irrigated acres of pre-independence state of Punjab. Each of these areas contains roughly twice times the arable land in Egypt. A substantial amount of research has been done on the development experience of the three areas mentioned above. Reviewing this literature is beyond the scope of the present paper. Interested readers may wish to consult Alan Richards, Egypt's Agricultural Development: Technical and Social Change, Westview Press, 1981, for both an account of agricultural development in Egypt and an extensive bibilography of materials on Egyptian agriculture. Richard Day and I.J. Singh, Developent as an Adaptive Process, Cambridge University Press, Cambridge, 1977, contains an insightful discussion of the Green Revolution in the Indian Punjab. Carl Gotsch and Gilbert Brown, "Agricultural Price Policy in Pakistan," World Bank Staff Paper No 120, provides recent materials on Pakistan. For a historical comparison of development in the Indian and Pakistan portions of the former State of Punjab, see Naved Hamid, "The Process of Agricultural Development: A Case Study of the Punjab", Unpublished Ph.D. dissertation, Stanford University, 1980.

in providing power for farming operations, especially those having to do with the intertillage of standing crops. However, in all three areas, the trade-off between the use of fodder for power and its use in the lucrative production of meat and milk, is altering the composition of the traditional herd.

But a closer study of the Egyptian agro-economic environment also reveals differences between it and similar lands in Southwest Asia. Average holding sizes, whether operated or owned, are small in all three areas. However, as Table 1 shows, there are marked differences in land distribution. Even if the means were similiar, differences in the distribution of land would have significant effects on strength of the public and private innovation signals that are being sent by the potential users of new technology.

Tenure relationships have also evolved differently. Legislation and administrative action following the Egyptian revolution gave substantial protection to the landless who farm the Nile Valley. At the other extreme are the various "land reforms" carried out in Pakistan, none of which could be said to have altered significantly the relationship between tenants and landowners. Agriculture in the Indian Punjab offers still a third environment in which owner-operators play a significant role in most agricultural communities.

Because the arid, irrigated environment permits year around plant growth, cropping intensities are high in all three areas. In the 1970's, further increases occurred in all regions when substantial investments were made in irrigation. In Egypt, the High Dam at Aswan provided year around water to virtually the entire irrigated area. In the Indian Punjab, the Bakra-Nangal project coupled with widespread private tubewell development provided both additional surface and ground water. Similarly, in Pakistan, Mangla Dam, in addition to replacing waters ceded to India in the Indus Basin treaty, added additional surface water to the sytem. More important for West Punjab, however, was the widespread groundwater development that took place under the auspice of both public and private investment.

The cost of water is important to farmers in both areas, albeit for rather different reasons. In Egypt, surface water is plentiful and, unlike India and Pakistan, there is no revenue assessment. However, the engineers who designed the Egyptian irrigation placed the canals and distributaries below grade with the result that water must be raised several feet in order to lift it to field level. Animal powered water lifting devices, different in design but similar in purpose, have been in widespread use in all three areas. Similarly also, the advent of electrical and diesel motor driven pumps are contributing to substantial changes in cropping patterns and livestock use.

An examination of the dual solutions to a number of programming models produced for the three areas leads to the conclusion that agro-climatic effects are important determinants of the pressures for mechanization.[11] In each of the studies examined, for example, the shadow prices for virtually all domestic resources, e.g., land, labor and animal power, were highest

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[11] For Egypt, the studies reviewed include Charles N'Cho, et al., "Agricultural Policy Experiments with the Water Master Plan Model", Food Research Insititue, Stanford University, 1983 and Carl Gotsch and Wayne Dyer, "Public Policy and the Demand for Mechanization in Egypt", UC/MOA Agricultural Development Sytems Project, Cairo, 1983. Indian results are to be found in a series of papers by I.J. Singh, a summary of which is con-Richard Day and I.J. Singh, Economic Development as an Adaptive Process: Green Revolution in the Indian Punjab, Cambridge University Press, Cambridge, 1977 A number of Pakistan studies have been brought together in Carl H. Gotsch, et al., "Linear Programming and Agricultural Policy: Micro Studies in the Pakistan Punjab," Food Research Institute Studies, Vol XIV, No. 1, 1975.

during the period when planting and harvesting overlapped. The only exception was water whose scarcity value, at least in the arid parts of India and Pakistan, increases with the decline in the availability of surface water following the post-monsoon run-off. (Under historical conditions, the shortage of water in the winter months resulted in substantial fallow land each year.)

Role of Government Policy: The most apparent difference between agricultural development in Egypt and Indo-Pakistan, however, have been in the degree of direct government involvement in resource allocation decisions. Detailed accounts of Egypt's agricultural policies may be found in a number of references and will not be reviewed here.[12] Suffice it to say that following the overthrow of the Farouk regime in 1952, a series of sweeping agrarian reforms during the following decade paved the way for government invervention in virtually every facet of agricultural activity. Admittedly, efforts to exert controls have not been 100 percent effective. For example, legislating cropping patterns in the face of conflicting price incentives has resulted in substantial acreage diversions and a resultant failure to meet production targets. Because of lucrative prices for livestock products, berseem (fodder) has been planted instead of the more economically profitable but financially unrewarding cotton. Fertilizers and pesticides, also provided to farmers on the basis of their acreage under "government crops," have been diverted to crops with uncontrolled prices such as vegetables and fruits.

[12] The most recent discussion is contained in the Report of a Presidential Mission: A Strategy for Accelerated Agricultural Development, AID, Cairo, 1982. See especially Annex II (Agricultural Policy: A Scenario for Adjustment).

Nevertheless, as an essay in this volume suggests, the impact of the government's administrative presence affected the allocation of resources in a significant way.

While the Government bureaucratic presence was much less in evidence in India and Pakistan, the empirical studies mentioned above make clear that agricultural incentives were influenced in both areas by government intervention. For example, as in the case of Egypt, cotton was taxed as part of the country's industrial policy as well as to provide revenues to the treasury.

On of the most interesting conclusions that emerges from a review of various modeling exercises that have sought to analyze the impact of government price policies on mechanization, is the variety of indirect mechanisms that can produce similar signals from the benefits matrix. For example, the in-depth study of the Indian Punjab by Day and Singh suggests that the rapid mechanization that occurred during the Green Revolution was in considerable measure a consequence of the introduction of high yielding varieties.[13] The dramatic improvement in the comparative advantage of wheat, which competes with fodder for land during the winter months, raised the opportunity cost of livestock for power and made tractors an attractive investment. In Egypt, a different mechanism involving fodder and livestock was at work, but one which produced similar consequences. Because wheat and long-staple cotton, both heavily taxed crops, compete with fodder in ways similar to the Pakistan case, it might be thought that animal power would continue to have a comparative advantage. However, because livestock product prices have been uncontrolled, the opportunity cost of fodder for animal power (as opposed to animal products such as meat and milk) has been high with the

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13 Day and Singh, op.cit

result that mechanization has been encouraged. (In addition, energy has been highly subsidized which has also worked in favor of mechanization.)

Macro policies have also had significant effects on the pace of mechanization. In the Pakistan studies, for example, there is clear evidence that had it not been for government sales of tractors at official exchanges rates when the rupee was highly overvalued, the demand for tractors would have been reduced significantly. In Egypt, macro policies involving labor have also been important. Permitting unrestricted migration to the Gulf States, for example, has produced a signficant rise in real wages which in turn has played an important role in encouraging mechanization.

The conclusions drawn from the review of the expected benefits matrix produced by various linear programming studies are two:

1. The similarity of the agro-climatic environment does show through in that the overlap in planting and harveting dates produces high shadow prices for most domestic resources and points to the types of innovations that would be induced by the scarcity of domestic resources.

2. However, government policy has also played a signficant role in influencing the type of mechanical inputs that profit maximizing farmers would regard as desirable. As noted earlier, when government policies distort the prices of inputs and outputs significantly, they may induce innovation and diffusion that is undesirable from a social point of view.

The Supply of Mechnical Technology in Egypt, India and Pakistan

Visitors interested in economic development usually come away from the Indian Punjab more impressed with the activities that are going on in the nonfarm sector than with results of the Green Revolution. This is not because the latter have been inconsequential, but because the sectoral interactions prescribed by textbook models of development that are everywhere obvious, are relatively rare in developing countries.

Evidence of linkages between the farm and nonfarm sectors is nowhere more easily found than in the machine shops and repair facilities for agricultural implements. An extensive history of these developments, and ideas about the extent to which cultural phenomena have played a role in their evolution, is beyond the scope of this report. However, the studies of the Punjab's development referred to earlier can provide conclusions which can be compared the "supply side" of technological innovation in Egypt and Pakistan.

The conceptual framework for ogranizing information about the small-scale manufacturing industry is the same Figure 1 used for describing the demand and supply of innovations in agriculture. Entreprenuers are assumed to be searching for technology that will augment scarce resources of labor and capital. This search is guided by the shadow prices that are generated by the solution to the problem of maximizing profits subject to constraints. However, when viewed from the perspective of the supply of agricultural technology, it is the output side of the picture, rather than the value imputed to resources, that is of major interest.[14]

The analogy between the agro-climatic environment of agriculture and the economic environment of machine shops is perhaps somewhat strained. However, for the private sector, the socio-economic structure of the agricultural sector is obviously an important determinant of the types of tools and implements that are produced. In several ways, the Indian Punjab has provided an ideal environment for fostering a dynamic, small-scale

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[14] In programming jargon, the primary concern is with the "primal" rather than the "dual" solution of the machine shop model.)

manufacturing sector.

1. There have been no cultural barriers that inhibited the development of skills in handling machines. The artisan class among the Sikhs has been a source of dynamism and entreprenurial activity. Consequently, the evolution of shops that produced the plows, harrows, fodder choppers and hand tools of for traditional agriculture into shops that provided pumps and threshers, did not involve a substantial discontinuity. Previous linkages to the agricultural sector were maintained by the expanding small-scale manufacturing sector.

2. The size and distribution of holdings in the Indian Punjab created a mass market for small-scale technology. The emergence of such a market requires a balance between (a) a large number of potential demanders in a relatively homogeneous size catagory, and (b) an absolute holding size that is sufficiently large so that farmers are able to generate the surplus needed to translate latent demand into effective demand. (The fact that many members of the small farmer class in the Indian Punjab were large farmers before they fled Pakistan at Independence has also frequently been cited as an explanation of the agressive search for technology from the demand side.)

3. Price and income policies in the agricultural sector created surpluses which could be spent on mechanization. It is clear that during the 1970's, the Indian Federal government understood that developing the irrigated Northwest was the only way of mitigating the food deficits that had become a major drag on development. As a result, a great deal of attention was paid to providing price incentives that, coupled with the increased productivity of the high yielding varieties, would generate a healthy agricultural sector capable of producing a substantial marketed surplus of wheat and rice.

In addition to these "environmental" effects, government industrial policies also contributed to the emergence of a dynamic small scale manufacturing sector. Among the most significant was the provision of pig iron from government steel mills at subsidized prices. As a result, the real cost of a low-lift pump set to the Indian small farmer was half of the price paid by his counterpart in neighboring Pakistan.[15]

Little has been done to document the sources of ideas for the continued improvement of machines that has gone on in the Indian Punjab. Anecdotal evidence suggests, for example, that a major local innovation, the thresher, resulted from the overwhelming wheat harvest of 1968 when the Indian Punjab recorded a 20 percent increase in output in one year. The threshing problem that this presented prompted a number of farmers to first push the wheat through the traditional fodder chopper as a way of lessening the tractor and bullock time required to reduce the harvested wheat to chaff suitable for winnowing. As the story is told, the flying wheat straw prompted the more innovative individuals to add a steel housing to the chopper in order to contain the straw. Still later, a fan was added in order to reduce the time required to winnow the wheat. The result in the 1970's was a machine that not only threshed wheat, but of equal importance, reduced the straw to a chaff that could be fed to livestock.

Active interest in the development of mechanical technology was present at the Punjab Agricultural University at Ludihana. For example, the goal of

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15 For a detailed comparison of incentives to purchase irrigation equipment in the Indian and Pakistan Punjabs, see Carl Gotsch, "Agricultural Mechanization in the Punjab," in Land Tenure and Peasant in South Asia, ed. Robert Frykenberg, University of Hawaii Press, 1978.

the Mechanical Engineering Department was the mechanization of a "10 h.p. farm" on which a range of tasks including tillage, threshing, water pumping, etc., was to be accomplished with implements that would use a single detachable power source.

The University's interest in appropriate technology is unique and commendable. However, conversations with agriculturalists and machine shop owners seem to bear out Binswanger's generalization that most ideas for mechanical innovations have come from farmers themselves.[16] They have the necessary feeling for how the task with which they are confronted must be accomplished, even if they lack the skills to complete the implementation of the idea.

It has always been difficult to understand why the interaction between the farm and nonfarm sector in the Pakistan Punjab has not been as intense as in neighboring India. It may be that much of the explanation is to be found in the fact that the Indian Punjab has a market of 600 million people to which its wares can be sold and that much of dynamics in the small-scale manufacturing sector can be traced to market size. Moreover, Federal planners in charge agricultural policy and agricultural research resources could treat the Punjab as a region of the country which could be nurtured in order to be able to deal with the national food deficit.[17] There have always been complaints from other Indian States about favoritism toward those areas that were already well off. Accelerated increases in food output were, however,

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16 A variety of generalizations about the innovation and diffusion of mechanical technology can be found in Hans Binswanger, "Agricultural Mechanization: A Comparative Historical Perspective," Discussion Paper, (Report No. ARU 1), Operational Policy Staff, World Bank, October, 1982.

17 Currently, approximately 80 to 90 percent of the food that goes into the system of national ration shops is procurred in the states of Punjab, Haryana and Utter Pradesh--the irrigated areas of the northwestern plains.

a cornerstone of both India' domestic growth and its international policy ambitions.

Pakistan could not afford to treat West Punjab as generously. Matching Indian price incentives, for example, would have had much wider economic repercussions at the national level than did the policies enjoyed by the East Punjab.

Lastly, there have also been rather persuasive arguments that what was called the "socio-economic" screen in Figure 1 played in role in determining the extent of the market in Pakistan. Hamid, in his exhaustive investigation of the history of agricultural development in the two areas, has emphasized the importance of the distribution of holding sizes in determining the market structure for agricultural technology.[18] The gist of the argument is that the presence of a group of relatively large number of farmers with substantial holdings diverted attention from the needs of the same small farmer group that has been so important in the agricultural development of the Indian Punjab. The result on the Pakistan side was a failure to develop the so-called "fractional" technology in pumps, motors, tubewells, threshers, etc., that has been the backbone of Indian mechanization. If true, it would have been precisely the kind of situation where the role public sector institutions could have been decisive in helping to stimulate activities in which private profitability and social efficiency diverged. (Hamid also goes on to make the argument that in the Pakistan case, the attention of public sector was, for political economy reasons, also fastened on the larger, "progressive" farmers.) The sum total of these explanations has been a private small-scale manufacturing sector in Pakistan that has not

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[18] Naved Hamid, op.cit.

developed the breadth and the innovative capacity of the Indian Punjab.

Whatever Pakitan's shortcomings, the interaction of farm and nonfarm sectors around the provision of agricultural machines is significantly more impressive than what has happened in Egypt. Earlier comments noted that a major difference between the agricultural sectors of India and Pakistan was the degree of administrative intervention by the government. Not only were the prices of commodities determined by the authorities, but farmers were prevented from responding to the incentives implied in the administered price structure by a mandatory procurements systems for several major crops. Similarly, inputs such as fertilizer and pesticides were made available primarily for crops in which policy makers had a special interest. Both procurment and the distribution of inputs was done through a system of government administered cooperatives. The result was the development of a system of agriculture in which individual incentives to search for improved technology were stifled.

Until recently, the supply of new mechanical technology in the Egyptian scheme was assumed to be the reponsiblity of the public sector. This in turn meant turning to public sector organizations in the nonfarm sector for sprayers, threshers, etc. (Tractors were imported by government agencies, frequently as a result of barter arrangements with Eastern European countries.) The link between farmers and the machine tool shops was thus a bureacratic one, uninformed by the private search for ways to improve farm income or sell machines. Instead, government engineers drew up specifications for the machines that were to be produced, they were fabricated in government machine shops and were given to the cooperatives to be put into use. There was little or no input from farmers themselves as to what was needed and no incentive for the producers of machines to find out what could be sold. The results have been predictable.

Because of the systemic nature of the problem, efforts to put Egypt on a more positive path with respect to the development and diffusion of appropriate mechanical technology will be difficult. On the one hand, the public sector has neither the politcal manadate nor the necessary bureaucratic resources to manage the innovation process. The Mechanization Institute and the revitalized Extension Service in the Ministry of Agriculture are still suffering birth pangs and are in no postion even to plan an approach to the problem let alone guide its implementation.

On the other hand, the private sector has shown little interest in becoming involved in producing mechanical equipment in any significant way. Thus far there has been some production of centrifigual or low-lift pumps but no appreciable investment in developing the marketing or distribution facilities that would be required to penetrate the rural areas. Conversations with machine shop managers reveals that they know little about the potential for the sale of agricultural implements and fear that producing equipment without clear demand signals would run a serious risk of leaving them with substantial inventories of machines they could not sell. (Part of the problem may also be that, given the relatively high Egyptian wage rates, they can not compete with the imported Indian pumps which are available in numbers throughout the Delta.)

The problems of trying to stimulate "markets" for innovation are revealed in the experience of the Ford Foundation/Catholic Relief Service efforts to introduce an axial flow thresher whose basic design was developed at the International Rice Research Institute in the Philippines. Difficulties were encountered on the supply side in that (1) the machine shops demanded that all off-take be guaranteed, (2) quality control was poor causing many of the machines to fail in the field. Difficulties were encountered on the demand side in arranging for the financing of the machines to farmers. A third party credit guarantee was required in order to persuade the Principal Bank for Development to loan the necessary funds to farmers who wanted to purchase the machines for custom service operations. Without the patience and determination of a third party acting as an intermediary in the market, the successful introduction of the machine into the sorghum growing areas of northern Egypt would never have occurred.

Conclusions

To those familiar with the difficulties enountered in bringing about technological change in agricultural sectors with heavy state involvement, the Egyptian scenario indicated above is familiar and requires little elaboration. It would be incorrect, of course, to jump to the conclusion that the lack of a linkage mechanism between the demanders and suppliers of technology is a <u>necessary</u> result of state intervention. The description of the Chinese approach to agricultural mechanization, for example, appears to be a case to the contrary. If the government is truely interested in the welfare of the rural areas and has entrusted a good portion of its political fortunes to their development, then the "latent" signals generated by the agro-climatic environment and relative prices are likely to be heeded. Moreover, if the necessary capacity on the supply side is not in place, no time need be lost in waiting for the perception of "markets" to emerge. The small factories required to produce the needed machines can become a part of the overall investment plan. Thus, when public sector organizations are available to play an effective role in "inducing" the supply of improved mechanical technology, their presence can provide important social benefits. For reasons noted earlier, market economies may contain inducement mechanisms, many outside the agricultural sector, that can lead to socially undesirable results. However, when reliance on the public sector also includes policies that eliminate the private sector, then the failure of public institutions to perform the functions of the market place leads to a complete breakdown of the inducement mechanism. It is, in short, the worst of all worlds