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## The Economics of Farm Mechanization and Processing in Developing Countries

REPORT ON AN ADC/RTN SEMINAR  
HELD AT MICHIGAN STATE UNIVERSITY  
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### Introduction

Many developing countries face major decisions on how rapidly they should mechanize their agriculture and on the role of the public and private sectors in this process. To ignore such decisions is to make them by default. The decisions are particularly acute since underemployment and unemployment are rising in many such countries. Mechanization involves the substitution of capital for labour, but there may also be a counterbalancing increase in the demand for labour following mechanization due to increases in cultivated acreage and crop intensity. Therefore, a careful empirical analysis is required if the outcome of each alternative policy is to be predicted.

Government has at its disposal an array of policies which affect mechanization. At the one extreme, government may simply allow mechanization to occur at the rate decided by free-market forces and accept the social consequences. At the other extreme, government may be directly involved in controlling the mechanization process. Policies which affect mechanization may conveniently be divided into short, medium and long-term categories. We define short-term policies as those directly affecting mechanization, such as sub-

sidized tractor-hire and the inclusion of mechanization in government agricultural projects. Medium-term policies are more indirect and less immediate in their impact, for example the establishment of a domestic machinery industry or minimum wage legislation. Long-term policies are the continuation of the other policies over several decades in accordance with some vision of the type of society to be established. Very roughly, short term policies have a horizon of 0-5 years, medium term policies of 5-15 years and long term policies of more than 15 years.

The economic analysis of mechanization policies may be considered at two levels of abstraction. First, there is the more technical question of the amount of change in output, employment and income which will result from each policy. Second, there is the question of *who* will bear the costs and *who* receive the benefits, i.e., what will be the result of each policy on the distribution of income, wealth and power in society?

Economists have often condemned rapid mechanization with only a rudimentary (if any) empirical analysis. They have made prescriptions which are clearly normative, such as "all factor-price distortions should be removed" or "mechanization is bad because it dis-

places labour." As several researchers have shown, the mechanization question is an empirical one which cannot be solved with rules of thumb or cursory analysis. Economists often condemn agricultural engineers for using such rules of thumb as "0.2 h.p. per acre is the minimum acceptable level" or the concept of a "mechanization ladder" as guidelines for policy-making, but the economists are equally guilty of reaching conclusions in the absence of thorough empirical analysis.

This ADC/RTN Seminar brought together a group of economists and one engineer, who were currently engaged in research on farm mechanization in developing countries in order to examine alternative methods of analysis. The report begins with a review of the major arguments in the mechanization controversy, continues with an examination of the different kinds of empirical research needed for policy analysis and concludes with some suggested redirections in research on the economics of farm mechanization in developing countries.

### **An Overview of the Mechanization Controversy**

Let us define mechanization as any form of power used to assist or replace hand labour in agriculture. This definition therefore includes ox-power, two-wheel tractors, four-wheel tractors, combines, mechanical threshers, etc. as types of mechanization. The controversy concerns whether government should encourage or discourage the increased mechanization of agriculture as part of its policy of agricultural development. The proponents of mechanization have included many agricultural engineers, who have emphasized the technical efficiency of greater mechanization, and the land-owning members of society, who view mechanization as a way to increase their own incomes, often via the displacement of tenants. The opponents of rapid mechanization have included most sociologists and economists, who have emphasized both the role of mechanization in creating unemployment and the unequal distribution among rural people of the benefits arising from mechanization. We consider the mechanization of agriculture to be inevitable, but the real questions are how rapidly the process of mechanization should be allowed to occur and what types of machinery are appropriate.

The heart of the controversy is the conflict between goals which occurs in any society. Let us suppose that government has some stated goals, such as increasing GNP, increasing employment and avoiding a very unequal distribution of income. Let us further suppose that government has two mechanization policies in mind: the first is to build a tractor-manufacturing plant and rapidly mechanize agriculture by providing tractors at a price less than the cost of production; the second is to impose very high import duties on tractors and fuel and to encourage the use of ox-

power via an agricultural extension service and credit agencies. Let us further suppose that the first policy leads to greater output, lower food prices, higher unemployment and a less equal distribution of income than the second policy. Which policy is the "right" one? That depends on the importance of one goal relative to another. Economists and engineers both try to assist government in policy-formation but, because they often place different values on the goals due to their particular disciplinary orientations, they give conflicting policy-advice. An example of this conflicting advice is illustrated by the following quotations concerning Pakistan. Giles, an agricultural engineer, emphasizes the importance of mechanization in increasing farm output. Bose and Clark, economists, emphasize the social consequences of such mechanization:

(There should be) . . . an expansion of tractors to meet the minimum 0.2 h.p./acre at the earliest (time), 1985 or earlier. This requires a minimum increase at a 12 percent compound rate starting with 4,000 tractors per year (averaging 35 usable h.p.) in 1966. (Giles, 1967, p. 22)

(If Giles' recommendations were implemented) . . . in 1975 the direct costs to society . . . would be about 330 million rupees and the direct benefits would be around 200 million rupees. . . . Similarly for other years direct social benefits would be considerably smaller than direct social costs. Moreover, the indirect social costs, mainly arising from throwing large numbers of farm labourers out of employment, may be considered much greater than the possible indirect benefits. (Bose and Clark, 1969, p. 294)

Having suggested that different policy-prescriptions arise primarily from differences in the weighting of goals, let us turn to the data and analyses from which prescriptions are drawn by economists. First, we must decide what sort of data are needed, i.e., we must decide what effects mechanization may have. Second, we then need to collect representative data to examine these effects. Table 1 is an example: it summarizes the types of losses and gains which may occur (and therefore need to be measured) for a single change when bullock-power is replaced by tractors. The most important *economic* changes concern possible increases in acreage cultivated, increased timelines and higher yields, changes in crop mixture, costs of machinery and fuel, saving of labour and saving of land previously used for bullock fodder. *Social* gains may include an increase in leisure and social losses may include unemployment and a widening of income differences.

Table 1 demonstrates the extremely large number of variables to be measured in evaluating the impact of a single change in technology on-farm. But the researcher still needs to aggregate over a representative sample of farms and villages if he wishes to reach conclusions on the way in which a certain regional or national level of mechanization would affect society's goals (of GNP, employment and equitable

Table 1. Village-Level Cost-Benefit Budget: An Example of a Change from Bullocks to Tractors

Losses <sup>a/</sup>	\$	Gains <sup>a/</sup>	\$
<u>Revenue Lost</u>		<u>Extra Revenue</u>	
Custom Work (Bullocks)	$H \cdot P_{HB}$	Yields Increase	$\Delta Q_1 \cdot P_Q$
		Crop Intensity Rises	$\Delta Q_2 \cdot P_Q$
		Crop Mixture Changes	$\Delta Q_3 \cdot P_Q$
		Acreage Increases	$\Delta A \cdot Q_A \cdot P_Q$
		Custom Work (Tractor)	$H \cdot P_{HT}$
		Alternative Use of Bullock Land	$A_B \cdot Q_A \cdot P_Q$
<u>Extra Costs</u>		<u>Costs Saved</u>	
Fuel, Service, Repairs	$M_T$	Bullocks' Concentrated Feed	$F \cdot P_F$
Hired Labour	$\Delta L_H \cdot P_L$	Hired Labour	$\Delta L_H \cdot P_L$
		Maintenance of Bullock Equipment	$M_B$
Loss of Cash Income	$\Delta Y_1$	Gain in Cash Income	$\Delta Y_2$
<u>Social Loss</u>		<u>Social Gain</u>	
Polarization of Income Distribution		Increase in Leisure and Decrease in Drudgery	
Increase in Unemployment		Increase in Prestige of Some Individuals	
Polarization of Village Structure			

Key

$\Delta Y_1$	= Loss of Cash Income	$L_H$	= Hired Labour
$\Delta Y_2$	= Gain in Cash Income	$F$	= Bullock Feed
$Q_1, \dots, Q_n$	= Outputs	$P_Q$	= Vector of Product Prices
$A$	= Acreage of Crops	$P_L$	= Wage Rate
$M_T$	= Tractor Running Costs	$P_F$	= Price of Bullock Feed
$M_B$	= Bullock-Equipment Running Costs	$P_{HB}$	= Price per Hour of Bullock Custom Work
$A_B$	= Bullock Land in Acres	$P_{HT}$	= Price per Hour of Tractor Custom Work

<sup>a/</sup>The gains and losses of income (or "cash flows") occur over many years but are shown for one year in the table. Internal Rate of Return is calculated from:

$$\sum_{t=1}^n \frac{\Delta Y_{2t} - \Delta Y_{1t}}{(1+r)^t} - C = 0$$

where,  $\Delta Y_{2t} - \Delta Y_{1t}$  = Change in cash flow in year t, C = Capital cost of project, n = Project life, r = internal rate of return.

Table 2. Classification of Economic Studies of Farm Mechanisation in Less Developed Countries\*

	Short-term (Static)				Medium-term (Dynamic)			Long-term (Perspective)	
	Cost-Benefit	Cross-Section	Linear Programming	General Equilibrium	Budgeting	Program-ming	Simulation	Historical	Instrumental
L u c a l	Baldwin [1957] Chancellor [1969] Dalton and Enikwaw [1971] Ellis [1972] b/ Green [1971] b/ Kolawole [1972] Laurent [1968] Lidman [1968] b/ Lord [1963] Peacock [1967] Purvis [1968] Renaut [1966] Van Wersch [1968] Weil [1970] Yudelman [1971]		Ahmad [1972] Clayton [1965] Gotsch [1973-a]						
R e g i o n a l	Chopra [1972] Gemmill [1971]	Donaldson and McInerney [1973] Inukat [1970] Johl [1970] Rao [1972]	Panagides and Ferreira [1970] Vaurs [1971]		Singh and Billings [1971]	Singh and Day [1972] Singh and Ahn [1972]		Day [1967]	
C o u n t r y w i d e	Bose and Clark [1969] b/ Kaneda [1969] b/ Timmer [1972-a] b/ Weitz-Hettelsater Engineers [1971]			Thirsk [1972] Sanders [1973]	Johnston, Cownie and Duff [1970] Johnston and Kilby [1972]		Johnson, et. al. [1971] Rossmiller, et. al. [1972]	Jasny [1936] Kautsky [1900] Marx [1966] Miller [1970] Mesa-Lago [1971] Roberts [1972] Wheelright and McFarlane [1970] Whetham [1970] White [1964]	Gotsch [1972] Schmitz and Seckler [1970]

a/ We include only those cited in the text.

b/ These cost-benefit studies were economic, rather than just financial in nature (see text for explanation).

income distribution). In this assessment the researcher also needs to look at possible backward linkages, such as employment in machinery manufacture, and forward linkages, such as lower food prices and hence higher real incomes leading in turn to increased consumption demand. In the discussion which follows we will look at different approaches to relating the losses and gains in reaching policy prescriptions.

### Methods of Analysis of Mechanization

A review of the literature reveals that most economic studies of mechanization, while using sophisticated methods of analysis, have relied on very dubious assumptions to compensate for their lack of representative data. Unjustifiably general conclusions have been drawn from studies of single mechanization schemes or limited geographical areas. Economic studies of mechanization have usually been the products of lone economists who have not had the resources to analyse a number of alternative technologies or to examine the interactions between technology and the labour, input (capital) and product markets. Few studies have looked at the effect of population growth on labour supply or have examined the sensitivity of their results to changes in some key parameters. Table 2 classifies some of the most important studies of mechanization according to the type of policy decision (short, medium or long-term) to which the research was, either implicitly or explicitly, directed.

This RTN seminar concentrated mainly on short and medium-term policy-research and the contributions by participants are included in Table 2. The application of the different methodologies shown in Table 2 will now be discussed, concentrating on the discussion which arose in the conference. We begin in the left-hand box of Table 2, the use of cost-benefit analysis for short-term policy decision on mechanization.

#### 1. Cost-Benefit Analysis

Our chosen study is that of Timmer (1972), on the choice of milling facilities for rice in Indonesia. An engineering firm completed an appraisal in 1971 and recommended that a small number of large, capital-intensive facilities be established throughout the country (Weitz-Hettelsater Engineers, 1971). The engineers conducted a *financial* cost-benefit analysis in which the costs and benefits were valued at current market prices. Timmer completed an *economic* cost-benefit analysis in which he corrected for certain distortions of the market price such as an overvalued currency exchange rate. More importantly, Timmer assumed that the real cost of labour was lower than the market-hiring price.<sup>1</sup> His conclusions were in direct contradic-

<sup>1</sup>This difference in method of pricing is the core of economic cost-benefit analysis. For a clear exposition see J. Price Gittinger, *The Economic Analysis of Agricultural Projects*. Baltimore: Johns Hopkins University Press, 1972.

tion with those of the engineers. The latter recommended equipment costing \$63.2 million and employing 7,300 people while Timmer recommended small power-mills at a cost of \$12.5 million and employing 14,700 people. Timmer's study ably demonstrates the importance of economic rationality rather than merely financial analysis for decision-making.

Timmer's study of processing differs from the usual study of the mechanization of agricultural production. Firstly, Timmer was provided by the engineers with a very full report on technical input-output relationships for the five types of mill under consideration. The provision of such data on alternative mechanization options for an entire country can be very expensive. Secondly, unlike rice-milling, agricultural production involves multiple products and has a seasonality in its demand for labour which make the assessment of benefits and costs (especially the real cost of labour) very difficult.

Cost-benefit analysis is the simplest approach to the appraisal of mechanization. It is very useful, but has generally been confined to a *single* alternative to the present system, when *many* alternatives may in fact exist. However, the method can handle multiple alternatives. A second shortcoming of many studies has been their concentration on financial rather than economic analysis for policy-making.

#### 2. Cross-Section and Time Series

A second approach to short-term policy research is to conduct a cross-section survey of farmers in an area where several levels of mechanization are in co-existence. Alternatively the researcher may do a "before" and "after" analysis of selected farmers thus constructing a time-series. Donaldson and McInerney (1973) attempted to combine both approaches—cross-section and time-series—in a study of the impact of tractors in Pakistan. They interviewed 208 farmers, located mainly in the Pakistan Punjab, who represented a 3.5 percent random sample of the farmers accepted for World Bank loans. The farmers were questioned about the 1966/67 (before loan) and 1969/70 (after loan) seasons. Only half of the farmers interviewed in 1971 had actually received loans, so the researchers believed that they would obtain a good comparison of mechanized and nonmechanized farms. Unfortunately the comparison was slightly blunted by the fact that most of the farmers who had not received loans had also mechanized their farms in the intervening period.

The usual approaches to analysing such surveys are to use chi-squared tests, analysis of variance and regression analysis. Donaldson and McInerney used chi-squared tests. Their major finding was that, following mechanization, farm size had grown by 240 percent. This growth was predominantly accomplished by the eviction of tenants, although some land was

brought into cultivation and other land was bought or rented.

The study of Donaldson and McInerney gave a very clear indication of the level of tenant eviction which followed mechanization in this area. However, several RTN Seminar participants had reservations about the sample used and the accuracy of recalled information on such parameters as cropping intensity. Nevertheless, the usual cross-section study has used even less accurate information and as a consequence, has attributed all observed changes to mechanization.<sup>2</sup>

### 3. Linear Programming

No paper on linear programming was presented at the RTN Seminar, although Carl Gotsch was present and had used this approach in conjunction with Bashir Ahmad (1972) in Pakistan. Linear programming is best suited to analyzing the impact of mechanization on individual farms, i.e., in a linear programming study one would analyze a small number of farms intensively rather than obtaining a broad overview such as comes from a cross-section survey. Bashir Ahmad conducted a small cross-section survey and then programmed a representative farm which had been extracted from the survey. By running the programme with different levels of mechanization, an indication of changes in output, income and employment following mechanization is given. Ahmad's chief finding was that the financial incentive to mechanize with tractors was very great if the farmer had a supplementary supply of water available.

The main problem of the linear programming approach is its assumption that the farmer maximizes profit subject to certain constraints. The overriding constraint of risk-aversion is not easily incorporated into this method. Nevertheless, it is probably the best tool available for short-term analysis on individual farms and this accounts for its widespread use in America and Western Europe.

### 4. General Equilibrium Models

Thirsk (1972-a, b) in Colombia and Sanders (1973) in Brazil have examined the factors influencing the rate of mechanization for a whole country, using aggregate data. These are "general equilibrium" studies because they begin by assuming that a country's factor and product markets are at a static equilibrium. They then attempt to show what equilibrium would exist under alternative factor and product prices. A discussion of Thirsk's study follows.

Thirsk was interested in discovering whether the Colombian Government's policy of providing credit for mechanization at half the market rate of interest

had increased or decreased GNP and employment, and whether the benefits of mechanization had accrued to (the owners of) land, labour or capital. Using data from a variety of sources, including a national farm management survey and the National Accounts, he estimated the elasticity of substitution between labour and capital in agriculture as approximately 1.4, a figure similar to that in other countries.<sup>3</sup> He then built a small simultaneous equations model of Colombian agriculture, concluding that the subsidization of mechanization had lowered GNP, favoured the capital-owning segment of society and resulted in lower agricultural employment.

Thirsk's work was analytically very elegant and did show the effect of one government policy. Such aggregate analysis would be a useful complement to micro-studies in moving from short-term into medium-term analysis. However, as Thirsk suggested, institutional questions such as land reform may be of much greater importance in Colombia's development than the question of whether to subsidize mechanization. The analysis did not indicate what "should be done next" with respect to policies for selectively mechanizing agriculture.

### 5. Recursive Programming of Representative Farms

This approach is in the medium term category, since it is an attempt to simultaneously examine production and investment through time in representative farms. Other possible medium-term approaches listed in Table 2 include simple budgeting through time, such as the work of Johnston, Cownie and Duff (1970), and the simulation approach to agricultural policy evaluation of Rossmiller, et. al. (1972).

At the seminar I. J. Singh discussed his work with recursive linear programming in the study of agricultural development in the Indian Punjab (Singh and Day, 1972). This work was not initially intended as a study of mechanization, but of the underlying factors in operation as agricultural development occurs. The study treated mechanization as one factor influencing the process of development.

The method consists essentially of a series of annual linear programmes, the constraints on one year's programme being dependent on the results of the previous year's programme. Using their model Singh and Day simulated the impact of new technology (including mechanization) in the Punjab for 1952-65 and also made projections to 1980. They predicted that the absolute demand for labour would decline 10 percent between 1970 and 1980 because of mechanization and this would result in a surplus of labour. The rate of mechanization was shown to be insensitive to small changes in wage and interest rates, hence the potential influence of government policy was severely limited.

<sup>3</sup> Sanders also found a similar figure in Brazil.

<sup>2</sup> For example, if higher yields follow mechanisation it is not necessarily correct to say that mechanization "caused" higher yields. The higher yields may have resulted from other changes, such as increased fertilizer, better seeds, improved irrigation, etc. which occurred at the same time as mechanization.

Recursive linear programming is undoubtedly a useful approach to analyzing firm growth over time, but its capacity to make regional projections is questionable since it treats a region as an aggregate of one or a small number of farm sizes.<sup>4</sup> Although changes in the pattern of land ownership, input industries and the labour market could possibly be incorporated, the resulting model would be a "monster." Perhaps recursive linear programming could be used for a micro analysis of representative farms in conjunction with a more conventional budgeting approach to macro appraisal.

#### 6. Long-Term Instrumental Research

These studies are concerned with showing the effects of different institutions on long-term development. An example is the work of Carl Gotsch (1972), who compared the impact of mechanization in Pakistan with that in Bangladesh, concluding that the impact in Pakistan had been less equitable due to the different institutions there. Notably, the distribution of land, capital and power in the two societies was different. In Bangladesh (divisible) tractor-hire had spread the benefits of mechanization whereas (indivisible) private ownership in Pakistan had led to eviction of tenants. Gotsch believed that economic studies needed to be integrated into a political and social framework if they were to be relevant for decision-making.

In the seminar, Gotsch expanded on his recommendations for policy-relevant research. He contended that it was not sufficient to present a decision-maker with some alternative policies. He urged researchers to find ways to actively implement their policy recommendations. The activist should be subtle, however. For example, it would be useless to condemn tractor mechanization when discussing the matter with a Minister if the latter's brother-in-law had a large farm benefiting from rapid mechanization. Gotsch felt that in such a situation the researcher would be wiser to demonstrate to the decision maker the trade-off between personal financial gain and potential social unrest following rapid mechanization and tenant-displacement.

Gotsch believed that institutional questions had received too little attention in the seminar. For example, tractor subsidization as a factor-price distortion was approximately equivalent in importance in most countries to agricultural taxation. Land reform was often of far greater importance in combating the spread of socially-undesirable mechanization than the removal of either subsidies or taxes.

Gotsch sketched out a block diagram of the general decision-making environment to show how the national regime, government bureaucracy and local power structure each influenced the choice of technology and

interacted with each other. He believed that the seminar had concentrated too narrowly on the simple economics of technological choice without concern for the political environment. In some countries, students, the military, and the urban populace might be more important in determining agricultural policy than anyone in the agricultural sector. Finally, on the question of methodology, Gotsch believed that no single approach was sufficient, but a combination of cross-section and time-series surveys was needed to provide the data for model building of some representative farms as well as giving a broader view to complement such model building.

There was disagreement by some participants on Gotsch's definition of the role of the economist. Some people argued that the greatest need at present was for an improvement of farm and regional-level analysis of income, employment and equity following mechanization. They believed one could not approach the decision-maker until a thorough, basic analysis had been completed. Other participants believed that the economist made allowance for the political environment by proposing an extreme policy, while really hoping to find acceptance for a more "palatable" second-best policy. To summarize this difference of viewpoint, Gotsch argued for an analysis of the effects of redistribution of property-rights (e.g., land reform) whereas traditional economic analysis takes the distribution of property-rights as given.

#### 7. Needed Redirections in Research on the Economics of Farm Mechanization in Developing countries.<sup>5</sup>

The participants were divided in the area on which they would lay greatest emphasis. Adherents to Gotsch's view believed that confronting policy-research with the political and social institutions of a country was the most important redirection. Others believed that revising the present methods of analysis and improving the data-base were more important. However, the following redirections might have been generally approved by the participants:

##### a. *Gearing Research to Short, Medium and Long-Term Policy Questions*

A large percentage of economic studies of farm mechanization have not clearly specified the policy questions being pursued. Research design should include an explicit statement of the policy questions to which the research is directed, in order that the research can be tailored to meet specific short, medium or long-term policy questions.

##### b. *Single Versus Multiple Mechanization Options*

Although studies of *single* mechanization options (e.g., tractor hire schemes) are relatively easy to carry out, they are of limited value to policy makers

<sup>4</sup> Singh and Ahn (1972) treated Southern Brazil as an aggregate of three farm sizes.

<sup>5</sup> This discussion is taken from Gemmill and Eicher (1973) and may not represent the views of all the RTN Seminar participants.

who are faced with choosing among alternative mechanization options. Research in the short and medium-term should emphasise the trade-offs inherent in alternative mechanization options for specific commodities, geographical areas, etc.

#### c. *Data Needs*

Much of the secondary data available through government farm surveys are inadequate for policy analysis on mechanization. Such surveys give background information (e.g., sizes of holdings, man/land ratios, implements in use, etc.), but cannot show the changes in output, income distribution and the demand for labour which follows mechanization. To estimate these variables, year-long micro-level surveys of farm production and rural non-farm activities are required.

#### d. *Short-Term Research*

Short-term research will continue to be an important service to policy-makers since urgent decisions on mechanization are taken every day. Single economists, or a small group of economists, carrying out short-term studies should take into account the following:

i. *Financial versus economic analysis.* Much of the confusion between engineers and economists (and frequently among economists) on mechanization stems from a lack of clear understanding that the (financial) profitability of mechanization to an individual or project may differ from its (economic) profitability to society. The economic profitability is calculated using prices which reflect the true scarcity of resources, i.e., in the economic analysis factor-price distortions, such as an overvalued currency exchange rate, are corrected. Both financial and economic analyses are essential for sound policy analysis. Economists have often accounted for a limited number of factor-price distortions without recognising that other such distortions may be counterbalancing. Research on factor-price distortions should be as comprehensive as possible.

ii. *Limited conclusions.* Many short-term studies have "masqueraded" as medium-term studies (i.e., they have drawn very general conclusions for whole regions or countries when they are only relevant to specific locations and the present time). It would be judicious for short-term researchers to recognize the limitations of their data and analysis.

iii. *Analytical techniques.* Cost-benefit analysis has proved useful at the local, regional and national levels. However, linear programming is a preferable tool for analyzing mechanization on individual farms, since a number of alternatives can be intensively studied with computational

ease. Although multiple regression analysis of cross-section data is potentially useful, it has been of limited use to policy-makers as a result of inadequate data and of the bias resulting from the omission of relevant variables. For example, the total increase in output in a region may wrongly be attributed to increasing mechanization when increased irrigation, which was not measured and not included in the regression analysis, may have been equally important.

#### e. *Medium-Term Research*

Economic research on mechanization per se is too narrow to guide policy-makers in the medium-term time horizon. Consequently, research on mechanization should be incorporated into a broader study of agricultural production systems which analyze the interactions between packages of technology and the labour, input (capital) and product markets. Such a study implies a team approach which includes economists, engineers, sociologists and technical experts (agronomists, soils specialists, etc.). Other important issues in carrying out medium-term research include:

i. *Methodological problems.* Operational methods for tracing the impact of mechanization on income, employment and income-distribution in the medium term are still in the formative stage. There is a need for further conceptual work, such as that of Gotsch (1972) and Thirsk (1972-a). A further need is for more research on the aggregation bias which occurs in the prediction of aggregate variables from representative micro-data.

ii. *Analytical techniques.* Budgeting is a standard and useful technique for elementary appraisal of a limited number of mechanization policies, but when many alternatives are being considered computer simulation is much more efficient. Unfortunately, most developing countries do not have sufficient and reliable micro-data for simulation to be useful in policy analysis at the present time. Although recursive linear programming (RLP) is not endorsed by many scholars, it has great appeal as a framework for making projections for individual farms through time. However, we are skeptical about its capabilities in aggregate analysis of alternative mechanization options. Clearly there is a need for more conceptual work on analytical techniques for the medium term.

#### f. *Selective Mechanization*

Mechanization is so country-and-commodity-specific that it is impossible to give general policy recommendations. It is also fruitless to discuss "a national mechanization strategy to minimize labour displacement" or "policies to maximize agricultural

development while minimizing social conflict." Researcher should recognise that there are trade-offs between the goals of agricultural development on the one hand, and avoidance of social conflict and labour displacement on the other hand. The most acceptable policy on mechanization will necessarily be a compromise between alternative goals. One type of policy which embodies such a compromise is concerned with selective mechanization to overcome seasonal labour bottlenecks. Once these bottlenecks have been identified, engineers and agronomists may direct their research to breaking them and the economists may devise policies which will encourage the selective mechanization of such bottlenecks, without leading to the mechanization of all farm operations.

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<sup>6</sup> Robert d'A. Shaw. *Jobs and Agricultural Development*. Monograph 3. Washington, D.C.: Overseas Development Council, 1970.

## Appendix 1

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