Some Basic Considerations on Agricultural Mechanization in West Pakistan

by

SWADESH R. BOSE and EDWIN H. CLARK II*

INTRODUCTION

West Pakistan is at present experiencing remarkable production increases in agriculture. These appear to be resulting from the rapid adoption of new varieties of seeds, the increased use of fertilizers and massive investments in tubewells — coupled with, during the 1968 *rabi* (winter) season, favourable weather conditions. Price-incentive policies, particularly agricultural price support, have helped considerably in the quick adoption of these innovations by farmers. A distinctive element of all the innovations so far promoted is that they are complementary to labour. There are virtually no economies of scale associated with their use. New seeds and fertilizers are as productive on small holdings as on large. The private tubewells are sufficiently inexpensive, even the small farmers can afford to invest in them, at least through partnership. Water, seeds and fertilizers are essentially infinitely divisible inputs. They can benefit the small farmers as much as the large.

The innovation being promoted as the next step in the process of rapid agricultural development is mechanization through tractors. But such mechanization, as is being proposed for West Pakistan, is essentially quite different from the innovations which have already been introduced. This mechanization is a substitute for, rather than a complement to, labour. All other countries which have mechanized their agriculture have done so because they began to experience labour shortages [for Japan, *see* 17 ; 24]. Pakistan proposes to mechanize in spite of a labour surplus. Such a policy may be clearly advantageous to the large farmers and they are eager to obtain tractors. But is such a policy socially advantageous?

We do not think that the answer to the question (at least the answer which seems to have been given) is obvious. Mechanization — because of the high

*The authors are, respectively, Senior Research Economist at the Pakistan Institute of Development Economics, Karachi, and Assistant Professor at Williams College, Mass., U.S.A., (formerly a Research Associate at the Institute).

costs and the substantial social, economic adjustments it will require — deserves careful investigation. Economic justification of such a policy should be based on net social advantage rather than private profitability.

This present paper is an attempt to make such preliminary investigation on the economics of agricultural mechanization in West Pakistan at this stage of development. Since adequate information is not available to make a rigorous and thorough study, we can only attempt to point out some of the many factors which should be taken into account and hope that the values we have given to these factors are at least of the proper order of magnitude. Most discussions of agricultural mechanization compare the situation under existing cultivation methods with that which might exist under completely mechanized agriculture. In our analysis we will be implicitly assuming that there is another alternative — improving the present techniques through the introduction of improved animal-drawn implements and partial mechanization of particular bottlenecks such as the threshing of wheat. This alternative, however, is not explicitly evaluated.

The paper is organized into four main sections. Section I deals with the direct benefits which may be expected from mechanization. Section II deals with the direct financial costs as they are measured by the farmer, and by the nation. Section III considers some of the indirect costs. Section IV considers the indirect benefits. At the end of the paper we summarize our findings and, mainly on the basis of the direct cost-benefit estimates, make the few tentative conclusions which can be drawn from a study undertaken on this level.

I. THE DIRECT BENEFITS OF MECHANIZATION

There are two major sources of direct benefits claimed for agricultural mechanization. The first is that it will increase the productivity of scarce resources used for crop production. The second is that it will release valuable resources now used to maintain draft animal power.

Mechanization and Increase in Yield

In countries such as the United States, Australia and even Japan where farm labour is a relatively scarce resource, mechanization has obvious benefits. In the case of Pakistan where labour is surplus and unemployment is serious, reduction of farm labour requirement as a result of mechanization, however profitable to the private farmer, is of little benefit to the society. Therefore, we may leave aside output per worker employed; this naturally increases because there is much less labour required under mechanization.

If mechanization increases the productivity of agriculture's other factor inputs, there will be increases in crop yield per acre. This may result from an improvement in both the quality and the speed of agricultural operations. A tractor can plough deeper and faster than a bullock. The only attempt which has been undertaken in Pakistan to measure such increases was a series of experiments conducted at Risalewala (Lyallpur) in the years 1951 through 1954 [9, pp. 225-230]. Four different farming systems were tried:

A — Individual tenants cooperating in the use of tractors.

B — Direct farming with as complete mechanization as possible.

C — Partial mechanization, 75% tractor 25% bullocks.

D — Tenants using tractors under a "joint management" supervision.

E — Individual farming by tenants with bullock power.

Essentially the same cropping pattern was followed under each system, except for fodder crops. The differences in yields varied, as is shown in Table I.1, which give the percentage that reported yields under systems A through D were of the reported yields under system E (traditional farming).

TABLE I.1

COMPARISON OF YIELDS UNDER DIFFERENT SYSTEMS OF FARMING, RISALEWALA: 1951-54

Farming system	Crops					
	sugarcane	Cotton	Maize	Wheat	Gram	*Rabi* oilseeds
A	113	105	166	121	190	120
B	123	56	96	115	138	105
C	117	79	97	149	114	119
D	113	78	169	143	142	140
Average	117	80	132	132	146	121

Unfortunately, no statistical test was made to determine the significance of these variations, although the percentage increases would seem to be high enough that a high statistical significance probably did exist.

There is no way of analysing what the particular reason for these increases might have been, if all other conditions, except the form of power used, were identical. Quality and speed are, to a large extent, substitutes for each other. If one has enough time one can sufficiently improve the quality of the operations regardless of how little power is available. In some cases this trade-off may not be a reasonable one. Obviously there are some operations which may take more power than is available from draft animals. Breaking up a deep hard-pan may be one of these. But these are specialised uses beyond the general mechanization being considered in this paper. In general, bullocks using proper implements can probably prepare land as well as tractors if they can spend enough time at it.

Thus, it would seem that time is the important constraint. If, for instance, crop planting is delayed beyond a certain "optimum" date, the yield will probably be reduced, and this reduction will be some function of the length of the delay. In West Pakistan this problem seems to be particularly important in getting the *kharif* (summer) crops planted. They are often delayed by a month or more beyond their optimum date because the bullocks needed for land preparation remain busy threshing the wheat. However, this bottleneck could be removed by mechanizing the threshing of wheat rather than the land preparation. Small mechanical or even hand-operated threshing machines could be produced by an already existing small-scale industry which is now manufacturing machinery for tubewells as well as other agricultural implements. In many cases such threshers could be operated by diesel engines or electric motors which are already used by the farmers for their tubewells.

For land preparation we might consider ways by which animal-powered operations can be speeded up. After all comparisons such as given above are comparisons between the traditional way of doing things and a new and different way. No account has been taken of what improvements can be made in the traditional methods to make them more productive as well. Yields are not higher solely because the pulling mechanism of the plough consumes petroleum rather than fodder. Reported per acre yields for "highly mechanized" farming in Japan in 1960 are not higher than those reported for land farmed by a "hoe" [5, Table 2]. After all the most striking characteristic of farming in the United States is not that per acre yields are so high — they were actually fairly low until acreage restrictions forced farmers to apply more fertilizers and other resources per cultivated acre — but that labour productivity is so high.

What improvements can be made in the traditional cultivation methods is a subject which is being largely ignored — especially in Pakistan. However, it is estimated that an improved bullock yoke increases power output by 60 per cent [5, p. 5]. Experiments in India have also shown that 18 hours per acre, using one pair of bullocks and one man, are required to prepare the seedbed well using the mouldboard plough, disc harrow and spike-tooth harrow. In contrast 94 hours per acre are required for the "desi" (traditional) plough and plank method [8, p. 26]. Similar results were obtained with experiments on different methods of puddling [8, p. 27] ; and, a good bullock-drawn seed drill "gave an average 12.5% increase in wheat yields with a 39.5% reduction in seeding time" [8, p. 28]. These results show that substantial improvements can be made in the traditional methods. Furthermore, the number of hours spent on an operation is rather less important than the number of days the operation takes. With better harnesses, better feeding, and better implements, bullocks could probably work both faster and more hours per day (the present average is below 5). Surely such improvements would drastically reduce, if not eliminate entirely, the apparent benefits of tractors in increasing the productivity of the associated agricultural inputs.

Thus, we believe that the question whether general agricultural mechanization would raise yield above what can be obtained more economically with improved, locally produced implements has not yet been satisfactorily answered.

Elimination of Bullocks[1]

Mechanization can increase the availability of resources for crop production by eliminating the need to feed draft animals. However, much of the food consumed by the draft-animal population comes from wheat straw, rice straw and forage which has an insignificant opportunity cost. The most obvious and important cost of animal power is the value of the resources tied up in producing fodder for the bullocks and the supporting population.

Contrary to many writings on this subject the major cost of fodder is not the land, but the water required for its production. Land is abundant in West Pakistan and has almost no value for agriculture unless it is irrigated — since most of the province receives insufficient rainfall to support crops. The value of agricultural land depends upon the availability of irrigation water. A recent comprehensive study of West Pakistan's irrigation and agriculture has concluded that there is only enough water available to the province (including groundwater and surface water) to irrigate about 29.3 million acres of land on a long-term basis at an average cropping intensity of about 150 per cent [15, pp. 27, 42]. At present there are about 26.5 million acres irrigated, and the average cropping intensity is about 100 per cent [15, pp. 27, 43]. Compared to these figures, the total cultivable land in the province is about 73 million acres [15, p. 26]. Thus, it is not land but water that is and will be the constraining resource. Keeping this in mind we can appreciate the basic fallacy in such claims as are made that with agricultural mechanization all of the presently fallow land will be brought under crops and cropping intensity will be raised.

In fact the only additional land that will become available with the elimination of draft-animal power will be that which can be irrigated by the water formerly used for the fodder. Assuming that about 50 per cent of *kharif* (summer) fodder will be replaced by cotton and the other 50 per cent by rice, we find that the replacement ratio is about one to one. That is, for every acre of *kharif* fodder eliminated, one acre of cotton/rice would be substituted. For *rabi* (winter) fodder, assuming that the resources will also be used to produce wheat,

[1]This subsection is based largely on the present authors' forthcoming paper "The Cost of Draft Animal Power in West Pakistan", [4].

the ratio is somewhat higher: 1.6 acres of wheat for every acre of *rabi* fodder[2]. Under present conditions the total social value (opportunity cost in terms of wheat, cotton and rice) of two cropped acres of fodder is about 505 rupees[3]. If we make some arbitrary adjustment to take account of wheat, cotton and rice yields increasing faster than fodder yields, we might take 600 rupees as an approximate measure of the social value of releasing two acres of fodder (one *rabi* and one *kharif*).

The next question is how much fodder acreage is used for a bullock and the supporting animals required to maintain (*i.e.*, provide replacements in perpetuity) one working bullock. The Indus Special Study found in its detailed surveys of farms throughout the Punjab and Sind that there are 0.6 cropped acres of fodder per bullock, which is split approximately 50 : 50 between *kharif* and *rabi* fodder [14, p. 65]. But adequate data about the livestock sector are not available to permit any direct estimation of the fodder acreage used for the draft-animal population (*i.e.*, bullocks and the supporting animals). We have, therefore, used the demographer's stable population theory to estimate indirectly the composition of the draft-animal population in terms of the numbers of young males, cows, and young females per working bullock for West Pakistan conditions[4]. Estimates of fodder requirements of each class (young males, young females and cows) of supporting animals are also available [14, p. 303]. Multiplying the estimated population of each class of supporting animals per bullock by its relative fodder consumption gives the total annual fodder consumption by the entire draft-animal population required to maintain one working bullock.

If the fodder consumption of a working bullock is taken as 1.0 animal unit, then the fodder consumption of the entire animal population required to maintain one working bullock works out to be nearly 2.0 animal units according to our best estimates of the values of the parameters involved [4]. This means that when the consumption of the supporting population is included, the number of cropped acres of fodder per working bullock is nearly doubled, *i.e.*, increased from 0.6 to nearly 1.2. We take it as 1.0 cropped acre roughly (0.5 *rabi* and 0.5 *kharif*).

---

[2]These ratios are estimated on the basis of water requirements for *rabi* and *kharif* fodder and other crops [32, Appendix D].

[3]In these calculations we have evaluated labour at zero cost. The average yields of seed cotton, paddy and wheat have been taken as 5.6 maunds, 21 maunds and 13 maunds respectively [14, pp. 153, 156, 181]. The farm-gate prices per maund estimated with reference to world market prices have been taken as 32, 15 and 13 rupees respectively [14]. The value of non-labour inputs purchased from the nonagricultural sector has been taken as 5 to 10 rupees per cropped acre. Thus, the opportunity cost of one acre of *kharif* fodder is 240 rupees and that of one acre of *rabi* fodder 265 rupees.

[4]The stable population model is an extension of the stationary population model and represents the permanent structure that a hypothetical population would ultimately have if the age-specific birth rates and death rates persisted without change [1, p. 133]. The actual parameters used in our estimates have been taken mainly from [12 ; 14], and the detailed results are reported in [4].

Thus, for every bullock which is eliminated by mechanization, one cropped acre of fodder would be released for the production of other crops (wheat, cotton, rice) with the water now used for the fodder crops. It follows from our earlier estimate that the approximate measure of social value of this substituted production is about one half of 600 rupees, *i.e.*, 300 rupees. If we add to this an estimate of the social value of the other food stuffs and associated resources required to support one member of the draft-animal population and deduct the estimated social value of meat, hides, manure, milk, *etc.*, obtained by raising one work animal and the supporting population, we find that the total net social cost per bullock is 500 to 600 rupees per year [details in 4]. This is the benefit the country should receive for every draft animal eliminated by mechanization on the presumption that good markets will be available for all the crops raised with the resources formerly devoted to supporting the bullock.

To convert this into the benefit per tractor, we must consider how many bullocks a tractor will replace. The average number of cropped acres per pair of bullocks has been found to be about 12.5 [14, p. 278]. However, this is significantly below their capacity which, even under present circumstances, is probably about 20 cropped acres per pair for the farm class of 25-99.9 acres, for owner as well as for tenant farms [12, p. 110]. We shall use this latter in our computations because mechanization is being proposed for large farms. If we assume that there will be an average of about 2 acres per rated horsepower (*i.e.*, one 50-HP tractor farming 100 acres), this would mean the benefit per horsepower of about 100 to 120 rupees per year, (*i.e.*, 1/5 of 500 to 600 rupees) or, say, 115 rupees on average. If we assume that the average tractor population will be equivalent to 3 acres per horsepower, then benefit per horsepower would be 150 to 180 rupees or, say, 165 rupees on average.

The direct benefit to the farmer is much greater than that to society. First, the internal prices received by the farmer — especially the supported prices of wheat and rice — are way above the world market prices which we used for estimating farm-gate prices relevant for social benefits. Secondly, the farmer benefits from mechanization because it reduces his labour requirements and allows him to get rid of his tenants from the land and keep their share — either one-third or one-half — of the produce to himself. The gross value of production per cropped acre was about 140 rupees in 1965 and is expected to rise to about 170 rupees in 1975 [10, p. 106]. Because of these factors, private benefits are very likely to be about double the social benefits.

If we assume that there are at present P horsepowers of tractors in West Pakistan and expect this to grow at the compound rate of g per year, then the average number of mechanical horsepower during any year is approximately:

$$P\,(1 + g)^{t-\frac{1}{2}}$$

If we denote annual direct financial benefits per horsepower by Ψ, the direct financial benefit from total mechanical horsepower in any year t is given by the following generalised expression:

(I.i) $B_f = \Psi P(1+g)^{t-\frac{1}{2}}$

For alternative values of Ψ, and various growth rates, estimates of social benefits in some future years are shown in Table I.2. The value of P is taken as 0.75 million in 1968 [8, Table VI].

TABLE I.2

DIRECT ANNUAL SOCIAL BENEFITS AT VARYING GROWTH RATES OF TRACTORS

(million rupees; at constant prices)

Growth rate, g (*per cent*)	Benefit per horse-power (*rupees*)	Year: 1970	1975	1980	1985	1990
		Total social benefit				
4	110	88	107	130	158	191
	165	131	160	194	236	287
12	110	98	172	304	535	943
	165	146	259	456	803	F.M.
20	110	109	270	672	F.M.	F.M.
	165	163	404	770	F.M.	F.M.

Note: F.M. means full mechanization.

When full mechanization is reached, the total annual direct benefit will be:

(I.ii) $B_{f'} = \Psi P'$

where P′ is the constant tractor horsepower required for full mechanization. P′, however, must be calculated by estimating how much acreage can be mechanized, and what the average horsepower per mechanized acre will be.

The amount of land mechanized depends upon the pattern of land ownership. Unfortunately no data on land ownership have been made public since the land reforms in 1958. At that time the ownership pattern was taken as shown in Table I.3.

TABLE I.3

LAND OWNERSHIP PATTERN IN WEST PAKISTAN

(A summary statement)

0-25 acres		25 acres and above	
No. of owners	area owned	No. of owners	area owned
(000's)	*(000 acres)*	*(000's)*	*(000 acres)*
4,719	22,864	349	25,778

Source : Compiled by the Planning Commission of Pakistan; quoted in [29].

Let us assume that a tractor can be used economically at least on a hire basis on any holding of 25 acres and above. The total number of acres in such holdings, reported in Table I.3, is about 25.8 million acres. After the land reforms, the government acquired about 2.2 million acres [13, p. 8]. All of the land was obtained from owners having more than 500 acres. Most of this acquired land has not been broken down into holdings below 25 acres. The total cultivable area (cultivated plus cultivable waste), reported in farm units of 25 acres and above by the 1960 Agricultural Census, was about 17.8 million acres (out of a total of 44.3 million reported acres) [25, p. 232].

Making some arbitrary adjustment for division of large land holdings through inheritance, fragmentation of holdings, possible joint cultivation of land to take advantage of mechanization as well as the fact that water may not be available to all of the culturable waste, or that the topography in some areas may not permit mechanization, we might estimate that there are about 20 million acres of land in West Pakistan susceptible to mechanization under the present land ownership pattern. For alternative mechanization densities of 2 acres per h.p. or 3 acres per h.p., the value of P′ becomes 10.0 million or 6.67 million respectively, but the annual direct social costs would be the same as is clearly shown in Table I.4.

TABLE I.4

DIRECT ANNUAL SOCIAL BENEFITS AT FULL MECHANIZATION

(million rupees; at constant prices)

(a) density 2 acres per h.p.	(b) density 3 acres per h.p.
110 × 10 = 1100	165 × 6.67 = 1100

As indicated earlier the corresponding annual direct private benefits in the aggregate would be about double the figures shown in Tables I.2 and I.4.

II. THE DIRECT COSTS OF MECHANIZATION

Two different measures of the direct costs of mechanization will be considered in this section. The first is the cost to the farmer — the amount he (in the aggregate) will pay to own and operate the tractors and their implements. We will call this the direct private financial cost. The second measure is the actual cost to the nation which we can take as the direct private financial cost less any direct duties or taxes plus any direct subsidies. We will call this the direct social financial costs.

Computing the direct financial costs is relatively straightforward. There are investment costs, fuel costs, maintenance and repair costs, and costs of drivers. These add up to the total financial costs.

It will be convenient for our purposes to consider mechanization in terms of the number of horsepower available rather than the number of tractors available. The price per horsepower is apparently sufficiently constant to allow cost computations to be made on this basis [6, p. 21]. To simplify matters, we shall use a steady-growth model varying the rate of growth of tractor horsepower from 4 per cent to 20 per cent per year, and compute the costs of actual financial outlays made during any year. At the end of this section we will briefly consider what the two different measures of these costs will amount to when the province reaches some level of full-tractor mechanization.

The Model for Cost Computation

If we assume that there are presently P horsepowers in the province and we expect this to grow at the compound rate of g per year, then after t years there will be $P(1+g)^t$ horsepower available. During the period $t-1$ to t, there will be a net increase in horsepower of:

$$P(1+g)^t - P(1+g)^{t-1} = P(1+g)^t \left[1 - \frac{1}{(1+g)}\right]$$

$$= P\,\frac{g\,(1+g)^t}{(1+g)}$$

The number needing replacement will depend both on g, the growth rate, and L, the average life of the tractor. In any year t, the required replacement will be equal to the sum of the net increases in tractor horsepower made L years previously, 2L years previously,...., nL years previously. If the growth process had been going on for an infinitely long time, the required replacement would be equal to:

$$P(1+g)^t \left[\frac{g}{(1+g)}\right]\left[\frac{1}{(1+g)^L - 1}\right]$$

The third term in this expression is the replacement factor. The first two terms will be recognized as the net increase during year t. If the introduction of tractors is a relatively recent occurrence, as it has been in Pakistan, the replacement factor would be somewhat less than that given above. We shall designate the actual replacement factor by d_g. Thus, the total investment required in any year t is equal to the net increase plus replacement, or:

$$\text{(II.i)} \qquad \text{Investment cost} = P\,(1+g)^t\;\frac{g\,(1+d\,)}{(1+g)}\;I$$

where I is the investment cost of one horsepower and the implements that need to go with it.

The fuel cost in any year t depends upon the average number of horsepower available during that year, the number of hours they operate and how hard they work, and is expressed by the following equation:

$$\text{(II.ii)} \qquad \text{Fuel cost} = P(1+g)^{t-\frac{1}{2}}\,(Vhf)\,F$$

where h is the average number of hours of operation during a year, f is the fuel consumption in gallons per (actual) horsepower hour, F is the cost per gallon of fuel and V is the ratio of the average horsepower output to the rated horsepower.

The normal procedure for treating repair and maintenance costs is to assume that they are a certain proportion, r, of the initial investment costs. However, it would be incorrect to add such a factor to the total annual investment costs expressed above. The total repair costs are spread over the lifetime of the tractor and are relatively light during the early years, compared to the later years. Normal maintenance costs should depend only on the number of hours the tractor works per year, and thus should be evenly distributed over its entire life. If the number of tractors were constant we could assume that the annual cost of repairs and maintenance would be some r times the total investment cost of the tractors in operation divided by their average life. This would be true because there should be an equal number of tractors in all age groups.

However, in a constantly growing tractor population there will be a higher proportion of newer tractors than under the situation where the population is constant. The relative proportions of new to old tractors will depend upon the growth rate, being higher for higher rates of growth. We can take account of this by multiplying an adjustment factor B_g to the quotient of the total investment for the tractors operating in any year divided by the average life of the tractor. In our model this would be represented by the following expression:

$$\text{(II.iii)} \qquad \text{Repair and maintenance cost} = P(1+g)^{t}\,\frac{rB_g I}{L}$$

The wages of the tractor drivers are equal to the average annual wage rate, W, times the number of tractors in use, assuming one driver for each tractor. If the average horsepower of the tractor is C, then the cost of operations in any year t is approximately[5]:

$$\text{(II.iv)} \qquad \text{Wage cost} = \frac{P}{C}\,(1+g)^{t-\frac{1}{2}}\,W$$

[5]This wage cost is a private cost. To the society the cost incurred in producing skills of drivers may be considered as the appropriate cost of tractor drivers. This, however, is of no significant magnitude compared to other costs, and the relevant equation is also rather cumbersome. Hence, the training cost is not included in the model but is discussed in Appendix A.

Adding all the separate cost items, given in the above expressions, we arrive at the total annual cost of mechanization for any year t, as follows:

$$\text{Total financial costs } TC_f = P(1+g)^t \frac{g(1+d_g)}{(1+g)} I + P(1+g)^{t-\frac{1}{2}} (Vhf)(F)$$

$$+ P(1+g)^t \frac{rB_g}{L} I + \frac{P}{C} (1+g)^{t-\frac{1}{2}} W$$

Simplifying, we get:

$$\text{(II.v)} \quad TC_f = P(1+g)^t \left[\frac{g(1+d_g)}{(1+g)} I + \frac{rB_g}{L} I + \frac{(Vhf)(F) + \frac{W}{C}}{(1+g)^{\frac{1}{2}}} \right]$$

The Values of Constants in the Model Used to Estimate Cost Flows

In computing the annual flows of direct financial costs, the values used for the constants in the model are shown in Table II.1 and those of d_g and B_g in Table II.2. Why these particular values have been used is briefly discussed here.

We have surveyed most of the leading tractor importers to determine the investment cost for tractors. For tractors in the 40 to 60 horsepower range, this cost averages about 290 rupees per horsepower ex-Karachi showroom and about 220 rupees per horsepower *c. & f.* Karachi. Another 8 to 10 per cent is required to transport the tractor to the farmer in the Punjab where most of the tractors are and will be used. Therefore, we can assume an average cost of about 310 rupees per horsepower[6].

The farmer must also purchase the various implements he needs to go with the tractor. The specific nature and cost of these implements will depend upon the farmer's specific cropping pattern, soil conditions, size of farms, *etc*. However, the importers are now bringing in implements for each tractor worth about 25 per cent of the tractor's basic cost. Apparently this is adequate for the present conditions. Adding 25 per cent to the basic cost of the tractors gives a total investment cost of about 390 rupees to the farmer.

In all these computations, since there is no direct tax or subsidy on the purchase of tractors or implements, the direct financial cost to the country will be the same as the direct financial cost to the farmer.

These are the costs which pertain at present. However, it is clear that to obtain the maximum benefit out of mechanization, the tractors will have to be used for many more operations than they are now. Two reports which have

[6]At the official rate of exchange of the rupee, this is equivalent to about 65 US dollars per h.p., while the cost per h.p. is 74 US dollars in Malaysia, and varies from 81 to 110 dollars in the United States [6, pp. 21-22; 7, p. 5].

studied the future of agricultural mechanization in West Pakistan recommend the purchase of implements whose total cost approximately equals the cost of the tractor, if the farmer is to make full use of his investment[7]. This will raise the total investment cost per horsepower to 620 rupees which we shall use in our computations.

One study estimates that the tractors should be used for an average of about 800 hours a year at an average V of about 0.5 [8, Table IX][8]. We shall use these values in our calculations. By doing so we shall, however, understate the total cost because the life of the tractor in years depends upon how many hours a year it operates. With a higher annual usage, the average life would be shorter, and thus the annual investment and repair costs would be higher. It has been suggested that in developing countries, the operating life of a tractor is 7-8 years when the annual usage is 800 hours, and the operating life becomes 5-6 years when the annual usage is 1200 hours [22, p. 67].

A study of new tractors in the United States working under half load showed an average fuel consumption of about .064 imperial gallons per horsepower hour (the U. S. gallon is smaller than the imperial gallon used in Pakistan) [8, Table IX; 22, p.14]. It seems unlikely that fuel consumption would be less in Pakistan than in the United States, and as the tractor gets older its fuel consumption would increase. Therefore, we will use a value of f of .067 gallons per horsepower hour.

The cost of the high-speed diesel oil used in tractors is about 2.12 rupees per gallon to the farmer [14, p. 294]. However, some of this cost is taken up by duties and taxes. After subtracting these the cost comes to about 1.00 rupee per gallon [11, p. 31] which, according to our definition, is the financial cost to the nation.

For tractors, the value of r recommended for use in the United States is 1.20 and that suggested for use in developing countries is 1.50 [22, p. 72]. However, these factors would apply only to the tractors and so we cannot use them directly with our measure of investment cost since this also includes the cost of the implements. Repairs and maintenance of the implements would probably be somewhat less than for the tractor itself. One survey in the United States found a level of repair costs of implements that would be equivalent to an r of about .36 [7, p. 8]. A value suggested for use in the developing countries by another source is equivalent to an r of about 1.2 [22, p. 68]. We will use a value of r equal to 1.0 for implements. However, since the implements are assumed to last twice as long as the tractor, this value of r has to be

---

[7] *See* [14, p. 293; 8, pp. 52-53].

[8] Another source [12, p. 108] states that tractors operate for as many as 1500 to 2000 hours per year in the Punjab. Much of this operating time is spent in such jobs as travel and road transportation which require a relatively low horsepower output. A higher value of h and a lower value of V are mutually offsetting in regard to fuel consumption.

divided by 2 before being averaged with the r value for tractors for use in our equation (II.iii). This gives a composite value of r equal to 1.00.

Appropriate values for B_g, shown in Table II.2, must also be arbitrarily assumed since we do not know the distribution of repair costs over the tractor's life.

A study of wages in the Punjab in 1964/65 found an average wage of 120 rupees per month including all prerequisites, such as meals and clothes [14, p. 297]. In the future the driver will have to be better trained than at present, so we will assume that the wage will be 150 rupees per month or 1800 rupees per year. We will also assume that the average tractor will be of 45 horsepower. However, in a labour-surplus situation market wages do not measure the direct social costs which may be taken as zero.

TABLE II.1

CONSTANTS USED TO COMPUTE DIRECT FINANCIAL COSTS

Constants	Units	Private cost calculation	Social cost calculation
P	horsepower	$.75 \times 10^6$	$.75 \times 10^6$
I	Rs./h.p.	620	620
r	—	1.00	1.00
L	years	7.5	7.5
V	—	0.50	0.50
h	hours	800	800
f	gal./h.p./hr.	.067	.067
F	Rs./gallon	2.12	1.00
W	Rs./year	1800	0
C	h.p./tractor	45	45

TABLE II.2

VALUES OF d_g AND B_g USED TO COMPUTE DIRECT FINANCIAL COSTS

g	4%	12%	20%
d_g	1.25	0.45	0.19
B_g	.98	.94	.88

Total Annual Direct Costs During the Mechanization Process

In Table II.3, we show the total annual flows of direct financial costs given by equation (II.v). The numerical values used in these computations have been indicated in Tables II.1 and II.2

TABLE II.3

TOTAL ANNUAL DIRECT COSTS AT VARYING GROWTH RATES g OF TRACTOR HORSEPOWER

(million rupees; at constant prices)

Growth rate, g	Cost measure	1970	1975	1980	1985	1990
4%	(a) Private	186	227	276	335	402
	(b) Social	131	159	193	235	282
12%	(a) Private	249	440	775	1,366	F.M.
	(b) Social	187	330	582	1,025	F.M.
20%	(a) Private	306	760	1,894	F.M.	F.M.
	(b) Social	239	594	1,480	F.M.	F.M.

Note: F.M. means full mechanization.

Total Annual Direct Cost at Full Mechanization

We can also estimate the total annual cost when full mechanization is reached. For this we need only slightly modify our equation (II.v). Then the total annual cost will be:

$$\text{(II.vi)} \qquad TC_{f'} = P' \left[\frac{3}{4L} I + \frac{r}{L} I + (Vhf)(F) + \frac{W}{C} \right]$$

where P′ is the constant total horsepower required, and other factors are as before, L = 5.5 years and h = 1200 hours for 3 acres per h.p. density (p. 285).

We have found in Section I that P′ is 10 million or 6.67 million for mechanization densities of 2 acres per h.p. or 3 acres per h.p., respectively.

TABLE II.4

ANNUAL DIRECT FINANCIAL COST UNDER CONSTANT TRACTOR POPULATION AT FULL MECHANIZATION

Cost measure	2 acres per h.p.	3 acres per h.p.
	(............*million rupees*............)	
Private	2,415	2,145
Social	1,715	1,580

Flows of Direct Costs in Relation to Direct Benefits

Since our computations for annual flows of direct benefits and direct costs in terms of rupees are based on identical assumptions about growth of mechanical horsepower, we can now give a generalised expression for net direct benefits in any year t as follows:

$$NB_f = B_f - TC_f$$

where NB_f is the net financial benefits, B_f stands for expression (I.i) and TC_f for (II.v). At full mechanization, annual net direct benefits are given by $B_{f'} - TC_{f'}$, where $B_{f'}$ stands for expression (I.ii) and $TC_{f'}$ for (II.vi).

One can easily see from Tables I.2 and II.3, and also from Tables I.4 and II.4, that annual direct costs exceed direct benefits. Towards the end of this paper, our conclusions will be based mainly on the comparison of these direct cost-benefit flows. Before that we shall discuss some of the possible indirect costs and benefits of mechanization which, however, are hard to quantify.

III. INDIRECT SOCIAL COSTS

There are certain important indirect social costs of massive mechanization. In this section we will indicate what some of these indirect costs are, and, where possible, estimate their order of magnitude.

Cost of Resettlement of Displaced Labourers

If tractors substitute for farm labour, as seems quite certain, then society is going to have to decide what to do with these unemployed persons. In Turkey where this problem was apparently not considered, "Most of the displaced workers stayed in villages and were forced to accept a lower standard of living" [31, p. 120]. Let us presume for the moment that the Government of Pakistan would not wish to follow a policy that would force people out of their existing jobs without making alternative jobs available for them. Let us investigate whether the number of jobs which can be expected to be created in the non-agricultural sector over the perspective-plan period (extending to 1985) will be adequate to absorb all the labourers likely to be displaced by mechanization plus the natural growth in the labour force. We may then estimate the investment that would be required to resettle the workers who would be displaced by mechanization.

Table III.1 shows two alternative projections of labour force in agriculture and nonagricultural sectors of West Pakistan. (The details about the projections are reported in Appendix B.) Labour force in the nonagricultural sector is projected on the basis of expected growth of output and labour productivity in that sector, as envisaged mainly in the Perspective Plan, and on the assumption that the proportion of unemployed in the total nonagricultural labour force remains unchanged over the period.

TABLE III.1

PROJECTIONS OF TOTAL NONAGRICULTURAL AND AGRICULTURAL LABOUR FORCE IN WEST PAKISTAN, 1965-85

(*Age 10 and above; in millions*).

Year →	1965	1970	1985	Annual compound rate of growth 1970—1985
Total labour force →	15.9	18.5	29.2	3.1
Projection I				
Nonagricultural	7.0	8.5	15.9	4.2
Agricultural	8.9	10.0	13.3	1.9
Projection II				
Nonagricultural	7.0	8.7	17.1	4.6
Agricultural	8.9	9.8	12.1	1.4

Source: see Appendix B.

These projections show that unless West Pakistan undergoes industrialization at a substantially more rapid rate than is planned, the agricultural sector will have to retain a large segment of the increase in labour force brought about by the increase in population. The labour force remaining on the farm will increase from an estimated 8.9 million in 1965 to 12 or 13.3 million in 1985.

Mechanization will certainly reduce agriculture's labour-absorptive capacity through reduction of labour requirement on mechanized large farms. It is not clear, however, what the labour force required on these farms would be after mechanization. Interviewing farmers in the Punjab who have mechanized, we received a remarkably consistent response that the labour force per acre had been reduced about 50 per cent from the pre-mechanization period[9]. It also appears from their answers that the post-mechanization labour force averaged about 4 persons per 100 acres compared to the pre-mechanization level of 8 persons per 100 acres. Let us assume that as agriculture becomes more intensive the labour requirement would increase to about 5 workers per 100 acres under mechanization.

It has been noted earlier that the farm area under holdings of 25 acres and above is nearly 18 million acres and that 20 million acres would be susceptible

[9]Another study based on 60 mechanized farms in the Punjab and Bahawalpur found that permanent labour on these farms declined from 2000 to only 340, out of which 100 were employed on tractors [30, p. 153]. This study also found that while tractor power reduced the permanent labour it stimulated demand for casual labour.

to mechanization partly through joint farming. Therefore, the pre-mechanization labour force on these large farms may be taken as 1.4 million or about 16 per cent of the total agricultural labour force in 1965. Estimates based on the 1960 Agricultural Census suggest a figure of 1 million or 11 per cent of total work force. In order not to overestimate labour displacement, we may assume that 1.2 million or 13 per cent of agricultural labour force is on large farms.

We can use a general relationship to calculate how much of the labour force would be affected by mechanization. Let N_t be the total labour force in the agricultural sector at any time t. A certain proportion, E, of the increase in labour force between time 0 and time t, $(N_t - N_0)$ would normally be absorbed into farms of size 25 acres or above. If N_0' is the labour force already on such farms at time 0, then their labour force at time t in the absence of mechanization would be:

$$\text{(III.i)} \qquad N_0' + E\,(N_t - N_0)$$

Let A' be the total acreage in the large farms which is susceptible to mechanization, A_t'', the acreage that would become mechanized at the end of time t with a labour force density of n''. Then the number of displaced labourers between time 0 and time t would be:

$$\text{(III-ii)} \qquad \frac{A_t''}{A'}\left[N_0' + E\,(N_t - N_0)\right] - A_t'' n''$$

The value of A_t'' would be a function of the growth rate of mechanization. We can further assume that the ratio of A_t'' to A' would be equal to the ratio of the amount of horsepower available in year t, $P\,(1 + g)^t$, to that available at full mechanization, P'. This makes our expression for the amount of labour displaced equal to:

$$\text{(III.iii)} \qquad \frac{P(1+g)^t}{p'}\left[N_0' + E\,(N_t - N_0) - A'n''\right]$$

This is the amount of labour which would be displaced through the number of years 0 to t. Adjustment of this expression to give the annual labour displacement produces a very complicated and clumsy mathematical formula. To simplify computations we will assume that the number of displaced people per mechanized horsepower will remain constant for every year during the entire period till full mechanization is achieved. In Section II, we have seen that the addition to tractor horsepower during any year t as a proportion of total tractor horsepower added during the period 0 to t is equal to:

$$\frac{P.\,g(1+g)^{t-1}}{P\,[(1+g)^t - 1]}$$

Multiplying this to expression (III.iii) we obtain the amount of labour displaced during any year t, as below:

$$\text{(III.iv)} \quad \frac{g(1+g)^{t-1}}{[(1+g)^t - 1)]} \cdot \frac{P(1+g)^t}{P'} \left[N'_0 + E(N_t - N_0) - A'n'' \right].$$

With this expression we tend to overstate the amount of labour displaced during the earlier years and underestimate the amount displaced during the later years.

Absorption of displaced labour in the nonagricultural sector involves residential cost, K_r, and employment cost, K_e. Multiplying expression (III.iv) by $(K_r + K_e)$ per worker gives the annual cost of resettlement.

We have already put values on many of the terms in this expression. N'_0 we estimated to be 1.2 million; n″ is 5 per 100 acres, *i.e.*, .05; N_0 for $0 = 1965$ is 8.9 million and N_t for $t = 1985$ is 13.3 million or 12.1 million under our alternative projections. A′ we estimated to be about 20 million acres. P is .75 million horsepower and P′ is 10.0 million or 6.67 million horsepower under alternative assumptions about mechanization density. The only variables left to be estimated are E, K_r and K_e.

For E, we can only choose arbitrary values depending upon our view of future events. If there were to be another land reform, the value of E might be pretty high. At the other extreme it may fall below the present ratio of N'_0 to N_0 which we estimated to be about 0.13. For the future we will assume the value of E to be 0.12

If we assume that full-tractor mechanization of farms of 25 acres and above would be achieved by 1985, our expressions indicate that labour displacement during the *entire period* would be about 0.6 to 0.7 million. If tractor horsepower grows at 12 per cent compound rate per year, the minimal estimate of labour displacement in the *year 1985* would be about .05 to .07 million.

On the basis of costs incurred by the Karachi Development Authority (K.D.A.) in providing low-cost housing to poor urban families in North Karachi and Korangi Schemes, we have estimated that the residential cost (K_r) of one worker with his family would be about 5,000 rupees (*see* Appendix C). Available data about capital-labour ratios in large-scale manufacturing, small-scale manufacturing, and transport and services indicate that the weighted average of required investment per worker employed in the nonagricultural sector would be at least around 10,000 rupees.

Thus, at resettlement cost of about 15,000 rupees per worker, an additional investment of about 10 billion rupees would be required during the next 16 or 17 years if full mechanization is to be achieved by 1985 and if the displaced workers are to be resettled with gainful employment in the nonagricultural sector. At a 12-per-cent growth rate of tractor horsepower the *annual* investment required to resettle workers displaced in one year, 1985, would be nearly one billion rupees.

These estimates are rather crude. But they surely indicate that even in a single year the resettlement cost of labourers displaced by mechanization would be very high. These estimates of costs of resettlement are, in a sense, unrealistic because the displaced farm labourers most likely would not be properly resettled, because such resettlement would require much faster growth of the nonagricultural sector beyond the rather optimistic rates we have already assumed for it. Therefore, the conclusion one must arrive at is that a large part of the increase in labour force would be left in the countryside without adequate employment, and that mechanization would worsen the situation than would otherwise prevail.

Other Indirect Costs

There are several other indirect costs of differing degrees of importance which would result from agricultural mechanization. Most of these are difficult or impossible to quantify in economic terms, but are nonetheless worth mentioning.

Meat Supply: The reduction in the availability of meat and hides has already been taken into account in computing the direct benefits and costs. However, it should be realised that the value we have used for the meat supply is the value at which it is presently sold in the market. The price of beef is among the lowest in the world. At present "The bulk of the beef available for consumption....comes from worn out, but not necessarily old, working bullocks or milk cows ...." [16, p.54]. At the low prices, which exist here, it would appear that commercial livestock production solely for the purpose of providing meat supply would be of dubious profitability, even on land which has a low opportunity cost [*see* 36, Chapter 6]. One would have to expect, therefore, that the price of meat would increase — perhaps substantially — if the bullocks were replaced and commercial livestock production substituted. This would lower still further the already distressingly low level of meat consumption in the province. The cost of reduction of meat supply will be greater than the figures used in our computation of direct benefits.

Backward Linkage Foregone: Among other indirect costs is one which could be called the cost of backward linkage foregone, and results from going for complete mechanization rather than the use of improved implements which could be manufactured by indigenous, labour-intensive small-scale industries.

Mechanization is likely to bring with it the establishment of tractor factories in the country. If they are just assembling plants, then domestic value added will be a low proportion of the total cost. If they are actually manufacturing plants, they will require a substantial investment of foreign exchange and will be absorbing capital that could be used elsewhere. If any special advantages are thought to be associated with the manufacturing of engines, it would seem that these advantages could be achieved as well by setting up plants to manufacture other forms of transport equipment for which there is adequate demand in Pakistan.

If the strategy were rather to push the production and use of improved bullock implements, this could be done by an almost entirely indigenous, small-scale industry such as has sprung up in the Punjab in support of the private tubewell development. Such industries have the advantages that *i*) they require little foreign exchange, *ii*) they are less capital intensive than the large-scale industries, *iii*) they induce savings that might not otherwise be made, and *iv*) they in turn have a strong "backward linkage" to other indigenous industries. The third point might need some elucidation. Only the big industrialists would be able to invest in a factory to manufacture tractors. They would undoubtedly be making these savings anyway, and investing them elsewhere if not in a tractor factory. The country would gain no additional investment resources, but only redirect the available resources from one use to another. In small-scale industry, however, the investor is often a labourer, shopkeeper or someone else on this economic level, who would probably not be making these savings were the profitable investment opportunity not available. Therefore, if the country presents this man with an investment opportunity, such as the manufacture of improved agricultural implements, it is increasing the net investment resources available in the country.

IV. INDIRECT BENEFITS

There may also be certain indirect benefits of mechanization which should be taken into account in analysing its advantages to society. The most obvious of these benefits are, however, rather difficult to quantify.

Creation of Mechanical Skills

First of all there is the benefit of learning which is usually ascribed to mechanization. With mechanization, a large proportion of the rural population would become familiar with machines at a young age and some of them would acquire skills in mechanical operations. This could be considered an indirect benefit since this familiarity would make it easier for such people to make the transition from agricultural to industrial employment. This benefit is real if it is true that one reason for industrial inefficiency in developing countries is that workers are not initially accustomed to working with machines.

Increased Savings in Agriculture

There is a well-known argument in favour of capital-intensive techniques even in a labour-surplus economy for the generation of larger savings for reinvestment. This argument implicitly assumes that those people who do not get employed in the newly developing capital-intensive sector would somehow be taken care of by the traditional sector. Although agricultural mechanization creates a somewhat different situation by displacing workers from their erstwhile employment, an indirect benefit of a capital-intensive (mechanized) agriculture might be that in the longer run it would result in an increased amount of savings in the agricultural sector, which would be available either for its further mechanization or for transfer to the industrial sector.

Thus, agricultural mechanization may, some time in the future, result in a net increase in the funds available for industrial development. As a result of this mechanism, agricultural mechanization can be considered as a long-term investment that will increase the availability of investment funds. Unfortunately, since it is difficult to predict the savings behaviour of the future agricultural capitalists — in the past, savings have apparently been quite low — we can estimate neither when this net flow to the industrial sector might start nor how large it might be.

CONCLUDING OBSERVATIONS

In this paper we have analysed the economics of mechanization in a situation of labour surplus, and have derived a series of expressions which would allow the computation of the flow of benefits and costs for any year during the mechanization process or after full mechanization is achieved. For West Pakistan it has been recommended that mechanization proceed at a rate of 12 per cent annually [8]. As an illustration of the implications of this recommendation, our analysis indicates that in 1975 the direct costs to society of such a programme would be about 330 million rupees, and the direct benefits would be around 200 million rupees. Thus, the net direct social cash flow in that year would be about minus 130 million rupees. Similarly for other years the 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. Thus, our cash-flow analysis indicates that mechanization is not socially advantageous.

However, this comparison is not a fair appraisal of the economics of the investment in mechanization since it considers only the net benefits during the investment period. Although the cash flow in the short run may be unfavourable because of the heavy investments required, the investment could be profitable in the longer run. For a rough analysis of this question, taking the present investment cost of 310 rupees per h.p. and 80 rupees for implements, we can compute the annual social cost (including depreciation interest at 10 per cent, maintenance and operating costs of the tractors and implements) to be about 175 rupees per horsepower. The estimated social benefit from disposing off work animals has already been found to lie between 110 and 165 rupees. This might be increased to take account of possibly higher yields resulting from mechanization. However, counterbalancing this is the fact that probably not all of the surplus animal power will be disposed off— at least not until the farmers can be assured that their tractors can be kept in proper operating condition. Thus, the direct social benefits of mechanization appear to be less than the direct social costs. There is no straightforward method of taking all the indirect costs and benefits into account in such an analysis, but it is apparent that if they were included the net benefit of mechanization to society would be significantly negative.

But mechanization appears to be profitable according to other analyses, and the farmers certainly seem to be eager to obtain tractors. The reasons for this lie in the significant divergence between social and private costs as well as benefits. Our cash-flow analysis has indicated private profitability of mechanization. This would be true even if private costs are estimated on the basis of a more normal investment analysis as we have just now roughly done for social costs.

The individual can purchase tractors at the official rate of exchange of the rupee without duties or taxes being added. Furthermore, to make this purchase he can obtain government loan at an interest rate of 6.5 per cent which is obviously below the opportunity cost of capital. These subsidies, however, are offset by taxes on fuel so that the roughly computed total annual cost (depreciation, interest, maintenance and operation excluding wages) to the farmer is about 200 rupees per horsepower, *i.e.*, 25 rupees above social costs.

Private benefits are, however, much higher than social benefits. For social-benefit calculation, we have evaluated the increased crop production resulting from mechanization at farm-gate prices which would be in balance with the world market prices if Pakistan were to become an exporter of these commodities at the official exchange rate. In fact, internal prices obtained by farmers are often above the world prices. Wheat, for example, is supported at 15 rupees per maund in the market. In 1968, this was 17 rupees. (The price would have to drop to about 11 rupees per maund at the farmer level if Pakistan were to export wheat without subsidies or a change in the exchange rate.) Furthermore, as we have seen, the farmers find mechanization profitable because in addition to bullock elimination it reduces farm-labour requirement and allows them to get rid of their tenant-farmers. Making adjustment for all these factors, we have estimated that the total annual direct benefit per horsepower to the farmer after paying wages is about double that to society or well over 200 rupees per horsepower. Thus, the net benefits of mechanization to the individual are clearly positive.

This divergence between the private and social net benefits arises mainly because the market prices are not appropriate to the economy's factor proportions. Capital and foreign exchange are clearly undervalued to farmers interested in mechanization. This imbalance could be corrected by changing official prices or imposing duties and taxes. A more difficult problem lies in the valuation of labour. To society, there is no cost to employing surplus labour at a subsistence wage in the agricultural sector if this labour has to be kept alive anyway. To the employer, however, there is a definite positive cost. To correct this imbalance would require either the subsidization of all labour employed in agriculture or the imposition on the employer of the cost of maintaining this labour whether he employs it or not. To subsidize the wages of all labour clearly is beyond the ability of the economic system. However, to effectively impose the costs of maintaining this labour on the farmer or potential employer is beyond the capability of the political system. It does not appear that the government can correct this imbalance under the existing system. Its only apparent operational means for discouraging the farmer from mechanizing would be to increase the cost of the initial investment until the divergence between private and social profitability were eliminated. This would require a tax on tractors of well over 100 per cent.

But the present remarkable growth of agricultural production in West Pakistan can be sustained without mechanization at this stage. It has been due mainly to higher-yielding seed varieties, increased fertilizer use and development of tubewell irrigation. Although the progress so far has been confined mainly to farms of large and upper-medium size ranges, this need not be so in the years to come. With a continuation of the rational policy of reliance on new seed varieties, increased fertilizer use, and extension of irrigation and plant protection, coupled with proper demonstration and increased credit facilities, the small farmers will also soon adopt these new and improved cultural practices. The fear that, unless large farms are mechanized now, the present rate of growth will soon taper off appears to be unfounded.

The huge resources that will be required for mechanization will tend to reduce resources available for other inputs such as fertilizers which are still in short supply and need to be increased enormously in future years in order to realise at a relatively low cost the great opportunities opened up by what may be called the seed-fertilizer-tubewell revolution in West Pakistan's agriculture.

Introduction of mechanical power should be made when it is complementary to labour and also when it may be necessary for certain operations which fall in the peak season of labour shortage. There is also scope for improving traditional ploughs, harnesses, harrows and other implements for cultural operations to be done better and faster.

We have not considered in depth or detail the important problem of export markets for agricultural products. It is highly important to examine whether it would be economical to expand the production of basic foodgrains beyond self-sufficiency, particularly through a costly programme of mechanization. Nowhere else in the world are such low-value crops as wheat and maize grown on irrigated land. Exports of such products may turn out to be socially costly for Pakistan. Thus, the importance of diversifying agricultural production, keeping in view the prospective pattern of home demand as income rises, and the export prospects abroad is underlined.

The conclusions we tried to draw from our study should not be considered definitive. But it is hoped that this paper has focussed on the central issues involved in agricultural mechanization, which need to be carefully investigated before such a costly programme is launched, and carried forward through fiscal and other incentives.

REFERENCES

1. Barclay, G. W., *Techniques of Population Analysis.* (New York: John Wiley & Sons, 1958).

2. Bean, L. L. *et al.*, *Population Projections for Pakistan, 1960-2000.* (Karachi: Pakistan Institute of Development Economics, January 1968).

3. Bose, S. R., "Labour Force and Employment in Pakistan, 1961-86: A Preliminary Analysis", *Pakistan Development Review,* Vol. III, No. 3, Autumn 1963.

4. Bose, S. R. and E. H. Clark II, "The Cost of Draft Animal Power in West Pakistan" forthcoming paper in *Pakistan Development Review.*

5. Buchele, Wesley F., "The Use of Energy for Food Production". Unpublished paper dated April 10, 1968.

6. Chanceller, Lee William C., *Selecting the Optimum-Sized Tractor from Developmental Agricultural Mechanization.* Paper presented at the 60th Annual Meeting of the American Society of Agricultural Engineers meeting jointly with the Canadian Society of Agricultural Engineering, Saskatoon, June 27-30, 1967.

7. Dawson, George R., *Costs of Owning and Operating Farm Machines.* (New Mexico: Agricultural Experiment Station, State University, March 1965).

8. Giles, G. W., *Towards a More Powerful Agriculture.* (Lahore: Planning Cell, Agriculture Department, Government of West Pakistan, November 1967).

9. Gill, Muhammad Shafi, *Fifty Years' Research in Agronomy, Dairy, Poultry Farming, Water Requirements of Crops, Mechanical Farming and Agricultural Extension*. (Lahore: Department of Agriculture, West Pakistan, 1960).

10. International Bank for Reconstruction and Development (IBRD), (International Agricultural Consulting Associates, Ltd), *Programme for the Development of Irrigation and Agriculture in West Pakistan, Comprehensive Report. Volume 7, Agriculture*. (Washington: IBRD. 1967).

11. I.B.R.D., *Programme for the Development of Irrigation and Agriculture in West Pakistan, Comprehensive Report: Vol. 2, Economics*, (Washington: IBRD, 1967).

12. I.B.R.D., *Programme for the Development of Irrigation and Agriculture in West Pakistan, Comprehensive Report: Vol. 9, Annexure 13, Farm Surveys*. (Washington: IBRD, 1966).

13. I.B.R.D., *Programme for the Development of Irrigation and Agriculture in West Pakistan, Comprehensive Report: Vol. 8, Annexure 10, Land Tenure*. (Washington: IBRD, May 1966).

14. I.B.R.D., *Programme for the Development of Irrigation and Agriculture in West Pakistan, Comprehensive Report: Vol. 10, Annexure 14, Watercourse Studies*. (Washington: IBRD, May 1966).

15. I.B.R.D., *Programme for the Development of Irrigation and Agriculture in West Pakistan, Comprehensive Report. Volume 5, Annexure 7, Water Supply and Distribution*. (Washington: IBRD, May 1968).

16. I.B.R.D., *Comparison of Agriculture in Sind and Punjab* by Hunting Technical Services Ltd., supporting documents to [14].

17. Johnston, Bruce, "Agricultural Development and Economic Transformation: A Comparative Study of Japanese Experience", *Food Research Institute Studies*, Vol. III, No. 3, November 1962.

18. Khan, A. R. and A. MacEwan, "A Multi-sectoral Analysis of Capital Requirements for Development Planning in Pakistan", *Pakistan Development Review*, Vol. VII, No. 4, Winter 1967.

19. Khan, Majid Hasan, *Second Five-Year Plan: Achievements and Evaluation of Work Done in Central Zone*. (Lyallpur: Agricultural Machinery Organization, Central Zone, 1965).

20. Khan, T. M. and A. Bergan, "Measurement of Structural Change in the Pakistan Economy: A Review of the National Income Estimate, 1949/50—1963/64", *Pakistan Development Review*, Summer 1966.

21. Khusro, A. M., *Economic Development with no Population Transfers.* Indian Institute of Economic Growth Occasional Paper No. 4. (Bombay: Asia Publishing House, 1962).

22. Lonnemark, H., *Multifarm Use of Agricultural Machinery.* Agricultural Development Paper No. 85. (Rome: Food and Agriculture Organisation, 1967).

23. Mahalanobis, P. C., "The Approach of Operation Research to Planning in India", *Sankhya,* (The Indian Journal of Statistics), Vol. 16, December 1955.

24. Ogura, T. (ed.), *Agricultural Development in Japan.* (Japan-FAO Association, 1963).

25. Pakistan, Ministry of Agriculture, Agricultural Census Organization, *Pakistan Census of Agriculture, 1960.* Volume II. (Karachi: Manager of Publications, October 1963).

26. Pakistan, Central Statistical Office, *Census of Manufacturing Industries, 1962/63. West Pakistan.* Mimeographed. (Karachi: Central Statistical Office).

27. Pakistan, Office of the Census Commissioner, Ministry of Home and Kashmir Affairs, Home Affairs Division, *Census of Pakistan, 1961, Vol. 3.* (Karachi: Manager of Publications).

28. Pakistan, Planning Commission, *The Third Five-Year Plan.* (Karachi: Manager of Publications, June 1965).

29. Pakistan, *Land Reforms Commission, 1959. West Pakistan Report.* (Lahore 1961).

30. Rafi-ud-Din, *An Investigation into Tractor Farming in the Punjab and the Thal.* Unpublished M.Sc. (Agr.) thesis, submitted to the Punjab University, 1953.

31. Shaw, A. O., "Tractor Versus Bullock Power" in the *Report of the First Machinery Conference and Exhibition,* Lahore, March 5-11, 1967, (Lahore: U.S. AID, May 1967).

32. Tipton and Kalmbach, Inc., *General Water and Reclamation Programme Project No. 5. Lower Rechna Doab.* (Lahore: WAPDA, August 1966).

33. West Pakistan, Agriculture Department, "Scheme for Development of Land and Provision of Machinery for Augmenting Water Supplies

in West Pakistan", P.C.I. Proforma, Feasibility Analysis (Revised), February 1968.

34. West Pakistan, Agricultural Machinery Organization, *Annual Report, 1967*. (Lyallpur: Agricultural Machinery Organization, Central Zone).

35. W.P.I.D.C., Small Industries Division, *Survey of Small Industries in Urban Areas of West Pakistan, 1961* (District Reports). (Lahore: W.P.I.D.C).

36. The White House, Department of Interior Panel on Waterlogging and Salinity in West Pakistan, *Report on Land and Water Development in the Indus Plain*. (Washington: The White House, January 1964).

Appendix A

SOCIAL COST OF TRAINING OF TRACTOR OPERATORS

Agricultural mechanization will require skilled drivers and mechanics to run and maintain the tractors. Some costs would be incurred if they were to be properly trained. Presumably, it is economical to properly train people to operate any machinery. Learning by doing is often an expensive type of education.

Training programmes for tractor drivers are presently being run by the Agricultural Machinery Organization in several locations [19 ; 33 ; 34] and by the Pakistan-German Cooperative Institute near Multan. In both instances the sessions run for six months although there is some thought that they should be longer. We can estimate what the costs of providing such training would be for the various rates of growth of mechanization.

Assuming that it would be necessary to train enough drivers in year t to operate the entire net increase in tractors during year t + 1 and assuming one driver for each tractor, the number of drivers required would be:

$$\frac{P}{C}\,\frac{g\,(1+g)^{t+1}}{(1+g)} = \frac{Pg}{C}\,(1+g)^{t}$$

where C is the average horsepower per tractor. The total financial cost of this training will be:

$$\frac{P}{C_m}\,(1+g)^{t}\left[g(1+d_g)\,I + (1+g)\,\frac{rB_g}{L}\,I + (1+g)^{\frac{1}{2}}\,(Vhf)\,F\right]$$

where m is the number of drivers that can be trained on one tractor during a year. Let us assume that for being trained each driver requires 100 hours of actual driving experience. Considering the time required for maintenance and repairs, probably no more than 15 drivers could be trained on one tractor during a 6-month period. This gives m a value of 30. It also means that h will be 3000 hours a year and, therefore, L will be only about 2½ years [22, p. 67]. All other variables will be assumed to have the same values as given in Tables II.1 and II.2 in Section II.

However, the costs given by the above expression are not the only costs involved in the training. Buildings have to be constructed, teachers hired, materials and tools provided and then the mechanics have to be trained as well (there would probably be no lack of broken down tractors for the mechanics to work on). The cost of all these other items would probably be proportional to the costs given by the above expression, so we can take them into account just by multiplying this expression by some constant, θ. What this constant would be is anyone's guess, but for the purposes of our calculations we will take it to be about 1.3.

Based on these assumptions, we can compute how the direct training costs of tractor drivers would change over time. These are shown in Table A.1.

TABLE A.1

ANNUAL COST OF TRAINING TRACTOR DRIVERS

(million rupees)

Year	Growth rate of tractors →	4%	12%	20%
1970		.38	.50	.64
1980		.58	1.51	3.70
1985		.69	2.65	—

(at 20% growth full mechanization would be achieved by 1980)

After the full-mechanization level is reached, training costs would drop to a low level because only the replacement drivers would have to be trained.

Appendix B

PROJECTIONS OF LABOUR FORCE IN AGRICULTURAL AND NONAGRICULTURAL SECTORS IN WEST PAKISTAN (1965-85)

Two alternative projections of labour force in West Pakistan's agriculture have been used in this paper. These have been residually obtained from independent projections of total and nonagricultural labour force, as briefly explained here. The projections of labour force in the nonagricultural sector are based on the expected growth of output and labour productivity in that sector.

The Planning Commission's projection of GNP for the country [28, p. 19, Table 1] is as follows:

(million rupees; at 1964/65 market prices)

	1965	1970	1975	1980	1985
I GNP	45,540	62,765	89,185	129,690	187,300

If, however, we use the Planning Commission's projected per capita incomes and populations of East and West Pakistan [28, pp. 24, 29, Tables 7 and 10], the following projection of GNP is obtained:

(million rupees; at 1964/65 market prices)

	1964/65	1969/70	1974/75	1979/80	1984/85
II GNP	43,428	59,576	83,966	121,520	173,912

The difference between these two projections of GNP for each period is as shown below (in million rupees):

	1965	1970	1975	1980	1985
I GNP — II GNP	2,112	3,189	5,849	8,170	13,388

Presumably, this difference arises partly from the use of calendar years in series I and fiscal years in series II, and partly from the nonallocation of some parts of GNP to either wing in series II. In an arbitrary, but not very unreasonable way, we have allocated these differences as under: For 1965, 1970 — 60 per cent to West Pakistan and 40 per cent to East Pakistan; for 1975, 1980, 1985 — 50 per cent to West Pakistan and 50 per cent to East Pakistan. This gives the projection of West Pakistan's GPP as shown in Table B.1. For sector-wise breakdown, it has been assumed that the share of agriculture in 1965 was 43 per cent of GPP, compared with 43.6 per cent for 1963/64 [20, p. 202]. The annual compound rate of growth of agriculture in West Pakistan is assumed to be 5.6 per cent which is envisaged for agriculture in Pakistan during the perspective-plan period, 1965-85 [28, p. 20, Table 2].

TABLE B.1

PROJECTION OF WEST PAKISTAN'S GROSS PROVINCIAL PRODUCT, AND THE SHARES OF AGRICULTURE AND NONAGRICULTURE (1965-85)

(million rupees; at 1964/65 market prices)

	1965	1970	1975	1980	1985	1965-85 annual compound rate of growth
Gross Provincial Product of which:	23,913 (100)	32,286 (100)	43,931 (100)	60,575 (100)	83,864 (100)	6.5
Agriculture	10,282 (43)	13,499 (41.8)	17,723 (40.3)	23,269 (38.4)	30,550 (36.4)	5.6
Nonagriculture	13,631 (57)	18,787 (58.2)	26,208 (59.7)	37,306 (61.6)	53,314 (63.6)	7.0

Note: Figures in brackets are per cent of GPP. *Source:* Based on [20 ; 28].

Two alternative assumptions are made about the future growth of labour productivity in the nonagricultural sector of West Pakistan. Alternative I is that it would be 2.50 per cent per annum compound during 1965-70 and 2.85 per cent during 1970-85. These rates of growth are implied in the perspective plan [28, Tables 2 and 8, pp. 20, 25] for the country as a whole. Alternative II is that the rate of productivity growth would be 2 per cent in West Pakistan during 1965-70 and 2.5 per cent during 1970-85, *i.e.*, the rate of growth of labour productivity would be below the national average in West Pakistan which had a more rapid growth of the nonagricultural sector in the past. The projection of output growth in the nonagricultural sector (Table B.1) is used alongwith these alternative assumptions of growth of labour productivity to project growth of employment in this sector.

The relationship between changes in output and in employment in the non-agricultural sector, used in the computations, is as follows:

$$\frac{\Delta L}{L} = \frac{\frac{\Delta X}{X} - \frac{\Delta P}{P}}{1 + \frac{\Delta P}{P}}$$

where X = output in the initial year;
L = employment in the initial year;
$P = \frac{X}{L}$ = labour productivity in the initial year;

$\frac{\Delta X}{X}$, $\frac{\Delta L}{L}$ and $\frac{\Delta P}{P}$ are respectively the per cent changes in output, employment and labour productivity in the same period.

The labour-force projections are shown in Table B.2 with sources of the total labour-force projection and the initial size of the nonagricultural labour force. In any period, the difference between the projected labour force and nonagricultural employment is the residual labour force remaining on the farm. It should be pointed out that the nature of our projections is such that nonagricultural "employment" also includes unemployed labourers in the nonagricultural sector. The proportion of unemployed in the nonagricultural labour force is assumed to remain unchanged over the period we are concerned with.

TABLE B.2

PROJECTIONS OF TOTAL, NONAGRICULTURAL AND AGRICULTURAL LABOUR FORCE IN WEST PAKISTAN, 1965-85

(age 10 and above; in 000's)

	1965	1970	1975	1980	1985
Total	15,904	18,509	21,698	25,291	29,183
Nonagricultural:					
Alternative I	7,000	8,519	*n.e.*	*n.e.*	15,854
Alternative II	7,000	8,736	*n.e.*	*n.e.*	17,123
Agricultural:					
Alternative I	8,904	9,990	*n.e.*	*n.e.*	13,329
Alternative II	8,904	9,773	*n.e.*	*n.e.*	12,060

Sources and Notes: n.e. means not estimated. Total labour force based on *population Projection* (on Fertility Assumption III) by Bean *et al.*, [2, p. 91] and 1961 Census sex-age specific participation rates as modified in Bose [3, p. 39,4]. The estimate of nonagricultural labour force in 1965 is based on the assumption that 44 per cent of the total were in that sector. The Third Plan [28, p. 25] says that in 1965 10.40 million would be in the nonagricultural sector of Pakistan as a whoe. It is likely that about 1/3 of this would be in East Pakistan, although for 1961 the Census [27] showed that less than 1/3 of the total nonagricultural labour force was in East Pakistan.

Appendix C

COSTS OF RESETTLEMENT OF DISPLACED FARM LABOUR IN THE NONAGRICULTURAL SECTOR

If a farm labourer displaced by mechanization has to be resettled in the nonagricultural sector, the costs involved would be the sum of residential cost (K_r) and employment cost (K_e).

The residential cost per worker with his family will depend upon the type of housing and related facilities provided. Over the past 10 years the city of Karachi has undertaken a number of resettlement schemes in which the facilities provided have varied from the minimal to the elaborate. The "plot township" concept now being used probably exemplifies the lower extreme. In a "plot township" the Karachi Development Authority (KDA) merely sets aside an area of near desert, demarcates the plots and provides community water taps. Nothing is built and no streets are paved. The average cost to the KDA is from 3 to 4 rupees per square yard and this is the rate at which the plots (averaging about 100 square yards) are given on 99-year lease. Still some investment for housing has to be made by the family moving in, and as the scheme develops roads will be paved, transportation will become available and so forth. The total investment cost of such a scheme is undoubtedly higher than what KDA incurs, but it is difficult to estimate how much more since the subsequent investment is very diversified and much of it is non-monetized.

The North Karachi and Korangi Schemes, built between 1959 and 1963, probably represent the opposite extreme from the "plot townships". Here the K.D.A. built the houses, provided public and commercial amenity buildings, paved the roads, supplied water and sewerage distribution systems and undertook general landscaping. The Chief Engineer of the Korangi Scheme informs us that costs have risen perhaps 25 or 30 per cent since the time these schemes were built. He also estimates that about 20 per cent of the cost was for labour and the other 80 per cent for materials. Taking these factors into account, and estimating on the basis of data from various sources, the proportions of the total cost taken up by various taxes, we estimate that the per household residential cost in such a scheme now would be about 5,000 rupees, as shown in Table C.1.

TABLE C.1

RESIDENTIAL COSTS

(rupees per family at 1968 prices

	Total cost
Housing	2330
Roads and bridges	690
Sewerage — collection + treatment	400+50
Water supply — distribution + purification	840+10
Electricity — generation + distribution + house wiring	100+350+200
Storm water drainage	410
Landscaping	20
Amenity buildings	560
Land acquisition	490
Miscellaneous	200
	6650
Less land	490
	6160
Less 20% for labour	1210
Net social cost	4950

Sources: Data provided by some officials of KDA and Karachi Electric Supply Corporation.

The problem of what facilities are to be provided for the displaced workers must be decided by the government. However, it can be argued that there are substantial, if indirect, social disadvantages involved in substandard housing, and that the additional benefits of a scheme like Korangi are probably greater than the additional costs.

The capital-labour ratio in the nonagricultural sector shows the amount of capital required to provide employment to one person. For 1962/63 a set of capital-labour ratios computed for 18 types of large industries in West Pakistan indicate a range from about 4,000 to 250,000 rupees per worker. The mean — obtained by weighting the capital-labour ratio for each industry by its average daily employment — is 16,350 rupees per worker. This estimate is based on real replacement values of assets [18] which are twice the book values shown by the *Census of Manufacturing Industries* [26]. This estimate of capital requirement (over 16,000 rupees) per worker may appear to be rather high.

One study in India derived the replacement values of assets by simply doubling the book values, and obtained an estimate of capital requirement of 9,102 rupees per worker in the early 1950's [21, pp. 14, 20]. Although the capital intensity of individual industries may be considered roughly the same in the two countries, the composition of industries and the rupee value of capital goods are different. Taking into consideration these factors and the rise in the prices of capital goods since the early 1950's, we may assume that the capital requirement per worker in large-scale industry in West Pakistan is 12,000 rupees at the prices of the late 1960's.

Other subsectors, of course, will have lower capital-labour ratios. A study of small-scale industries in urban areas of West Pakistan, made in 1961, shows that the capital-labour ratio in small industries ranges from 1,000 to 4,000 rupees from one district to another, and the simple average of 24 districts comes to 2,227 rupees per worker [35]. As for transport and services, no such estimates are available for Pakistan. For India in the middle 1950's, Mahalanobis [23] used a figure of 3,750 rupees per worker. For West Pakistan, in the late 1960's we may rather arbitrarily assume that the required capital per worker in transport and services is around 5,000 rupees.

The data about distribution of nonagricultural labour force in these subsectors are not available. However, from the relative magnitudes of total value added and rough guesses about per worker value added in these subsectors, we assume that in the late 1960's the percentages of total nonagricultural labour force in large-scale industries, small-scale industries, and transport and services are 12, 18 and 70 respectively. Assuming no change of these proportions in the relevant future, the estimated (weighted) average capital-labour ratio, *i.e.*, capital requirement per worker in the nonagricultural sector as a whole comes out to be 5,340 rupees. Thus the residential cost, K_r, plus the employment cost, K_e, per labourer in the nonagricultural sector is over 10,000 rupees.