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SOME BASIC CONSIDERATIONS ON AGRICULTURAL MECHANIZATION IN WEST PAKISTAN

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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 that 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.

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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, 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 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 profit-ability.

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 tractors 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 technique 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. Since the question of the real cost of animal draft power to the society is so basic to the broader question of the economic benefits of mechanization, we have included an appendix in which we investigate the economics of draft power in some detail.

Section 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 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 gives the percentage that reported yields under systems A through D were of the reported yields system E (traditional farming).

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. 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.

Table I-1
Comparison of Yields Under Different Systems of
Farming - Risalewala - 1952-54

Farming System	Crops					Rabi Oilseeds
	Sugarcane	Cotton	Maize	Wheat	Gram	
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	<u>117</u>	<u>80</u>	<u>132</u>	<u>132</u>	<u>146</u>	<u>121</u>

Obviously there are some operations which may take more power than is available from draft animals. Breaking up a deep hardpan 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 the 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 that 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 mechanism pulling the plough consumes petroleum rather than fodder. Reported per acre yields for "highly mechanized" farming in Japan in 1961 are not higher than those reported for land farmed by a "hoe" [4, 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 supply 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 [4, 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 at 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 of whether mechanization increases yields has not yet been satisfactorily answered. However, one comes across the fallacious presumption of a cause and effect relationship between the apparent association of high yield levels and mechanization. Probably the most sophisticated form of this argument is that yields per acre and available horsepower per acre have a causal relationship [8]. It is asserted that present yields in West Pakistan (and in similar areas) are low due to inadequate horsepower available per acre, and mechanization by increasing horsepower per acre will lead to higher yields [8].^{1/}

But this hypothesis of a direct relationship between yields and available horsepower per acre is highly tenuous, even on the basis of the data used to support it. These data show [8, Appendix Figure 4], that yields per acre in Taiwan and U.A.R. are comparable to the yield in Europe and much higher than that in the U.S.A., although the former two countries have respectively 0.11 h.p. and 0.15 h.p. per acre while Europe and U.S.A. have 0.38 and 0.41 h.p. per acre respectively. Moreover, Latin America and Taiwan have equal horsepower available per acre, which

^{1/} In West Pakistan at present only 0.084 h.p. per acre is available from human, animal and mechanical sources (excluding stationary power units for irrigation etc.), while a range of 0.2 - 0.3 h.p. per acre is considered to be the minimum needed for high yields [8].

is not much higher than that in West Pakistan, India or Asia (excluding mainland China), but yields in Latin America and Taiwan are much higher.

Japan is cited as a country which has high yields per acre and high horsepower per acre. But we must emphasise that mechanization of agriculture in Japan has been introduced on a large scale only since the 1950's, under great pressure of labour shortages.

In the earlier period between 1881-90 and 1931-40, production of Japan's six major staple crops nearly doubled mainly as a result of increased crop yields. The area devoted to crops increased by only 18 per cent whereas yields rose by over 66 per cent [22, pp.226-27]. This large increase in yield was not associated with any large scale mechanization of major agricultural operations such as ploughing, weeding, sowing and harvesting. As a matter of fact, Japan's farm labour force seems to have declined very slightly during this period and labour-intensive cultivation on small farms using better seeds, fertilizers, pesticides and improved water supply was relied upon to raise output and yield [22, p.228]. The use of farm machinery and implements was much delayed as compared with the progress in rice breeding, irrigation and fertilizer application techniques [30, p.400].

The farm implements prevailing in Japan till about 1900 were nothing but hand tools. From 1900 onwards

these implements began to be improved, and short-bottom ploughs drawn by animals, foot-pedal rotary threshers, and inter-tillage weeders were developed. But till the end of World War I motive power supply sources other than human and animal power were extremely poor.

It was only after 1920 that petroleum engines and electric motors came into wide use in running pumps and processing machines. In the 1930's such power units began to be used also for threshing, husking and winnowing operations. Power threshers helped resolve the peak season (during wheat harvesting and rice transplanting) labour shortage. But till the end of World War II, ploughing was almost entirely done by animal power. Power tillers were introduced after 1930, but the number was only 98 in 1931, less than 3000 in 1939 and about 7500 in 1942 [30, p.414] and were confined to large farmers in particular areas. It was only after World War II and beginning in the 1950's that power tillers became widely used. Even in 1950 Japan had only 13,000 power tillers (i.e. garden-type tractors) and as few as 12 large-type tractors [30, Tables 21-1, 21-6].

It is clear, therefore, that in pre War years the use of power in Japan's agriculture was confined mainly to stationary machines such as irrigation or drainage pumps, threshers, huskers or winnowers. In mobile operations

such as ploughing, weeding, sowing and harvesting very little mechanized power was used. Only after a number of decades of rapid industrial growth resulting in a shortage of farm labour particularly since the 1950's that mechanization of these agricultural operations became increasingly important in Japan.

In Western countries as well the introduction of tractors and harvestors have been made as a labour saving device in response to farm labour shortages, and not for any intrinsic superiority of mechanical power over human and animal power in raising yields. There is hardly any valid reason why the issue of mechanization of agriculture in West Pakistan should not be viewed in this way. This is more so because in recent years, availability of new high-yielding seed varieties which are very responsive to fertilizer and other associated inputs has opened up great possibilities of yield increases without the use of mechanical power for cultural operations. These possibilities are realisable, as is evidenced by the very substantial progress West Pakistan farmers are making with the higher yielding varieties of wheat, rice and maize.

Benefits from elimination of bullocks

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 [17, pp.27, 42]. At present there are about 26.5 million acres irrigated, and the average cropping intensity is about 100 per cent [17, pp. 27, 43]. Compared to these figures, the total cultivable land in the province is

about 73 million acres [17, 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 animal draft power will be that which can be irrigated by the water formerly used for the fodder. Assuming that about fifty per cent of Kharif (summer) fodder will be replaced by cotton and the other fifty 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 all be used to produce wheat, 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 Rs.505.^{3/}

2/ These ratios are estimated on the basis of water requirements for Rabi and Kharif fodder and other crops [39, 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 [16; pp.153, 156, 181]. The farm gate prices per maund estimated with reference to world market prices have been taken as Rs.32, Rs.15 and Rs.13 respectively [16; 45]. The value of non-labour inputs purchased from the non-agricultural sector has been taken as Rs.5 to Rs.10 per cropped acre. Thus, the opportunity cost of one acre of Kharif fodder is Rs.240 and that of one acre of Rabi fodder Rs.265 (See appendix A for details).

If we make some arbitrary adjustment to take account of wheat, cotton and rice yields increasing faster than fodder yields, we might take Rs.600 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 [16, 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

^{4/} The stable population model is an extension of the stationary population models 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 [14; 16], and the detailed results are reported in appendix a.

requirements of each class (young males, young females and cows) of supporting animals are also available [16, p. 303-7]. 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. 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 1.0 roughly (0.5 Rabi and 0.5 Kharif).

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 by the fodder crops. It follows from our earlier discussion that the approximate measure of social value of this substituted production is about one half of Rs.600; i.e. Rs.300. If we add to this an

estimate of the social value of the other foodstuffs 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 Rs.500 to Rs.600 per year. 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 of 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 [16, 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 [14, p.110]. If we assume that there will be an average of about 2 acres per rated horsepower (i.e., one 50 H.P. tractor farming 100 acres), this would mean the benefit per horsepower of about Rs.100 to Rs.120 per year, or say Rs.115 on average. If we assume that the average tractor population will be

equivalent to 3 acres per horsepower, then the benefit per horsepower would be Rs.150 to Rs.180 or say Rs.165 on average. Again, assuming that there is an export market for the increased crop production, we have roughly calculated that the benefit measured in foreign exchange will be about Rs.100 and Rs.150 per horsepower for mechanization densities of 2 and 3 acres per horsepower respectively.

The direct benefit to the farmer is much greater than that to society. Firstly the internal prices - 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, he benefits from mechanization because it reduces his labour requirement 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 Rs.140 in 1965 and is expected to rise to about Rs.170 in 1975 [12, p.106-7]. 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 horsepower of tractors in West Pakistan and expect this to grow at the compound rate of g per year, the average number of mechanical horsepower during any year t is approximately:

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

If we devote 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:

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

For alternative values of Ψ , and various growth rates, estimates of social benefits in some future years are shown in Table I-1. 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	Benefit per horsepower	Total Social Benefit				
		1970	1975	1980	1985	1990
4%	Rs. 110	88	107	130	158	191
	Rs. 165	131	160	194	236	287
12%	Rs. 110	98	172	304	535	943
	Rs. 165	146	259	456	803	1415
20%	Rs. 110	109	270	672	1671	4158
	Rs. 165	163	404	770	2507	6237

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

$$(I.ii) \quad B_f' = \Psi P'$$

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 has been made public since the Land Reforms in 1958. At that time the ownership pattern was as shown in Table I-3.

Table I-3

Land Ownership Pattern in West Pakistan
(a summary statement)

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

Source: Compiled by the Planning Commission of Pakistan; quoted in [35].

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 [15, 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 in West Pakistan was about 17.8 million acres (out of a total of 44.3 million reported acres) [31, 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)

density ^(a)	density ^(b)
2 acres per h.p.	3 acres per h.p.
<u>110 x 10 = 1100</u>	<u>165 x 6.67 = 1100</u>

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.

Section II

Direct Financial Costs of Mechanization

Three different measures of the direct financial cost 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 and plus any direct subsidies. We will call this the direct national financial cost. The third measure is the direct foreign exchange cost of mechanization.

Computing the direct financial costs is relatively straightforward. There are investment costs, fuel costs, maintenance and repair costs and finally cost 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 [5, 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 three 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 horsepower 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:

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

The number needing replacement will depend both on g , the growth rate, and L , the average life of the tractors. 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:

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

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:

$$(II-i) \quad \text{Investment cost} = P (1 + g)^t \frac{g(1 + d_g)}{(1 + g)} I$$

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:

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

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:

$$(II-iii) \text{ Repair and Maintenance cost} = P(1 + g)^t \frac{r B I}{L}$$

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:

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

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: Total Financial Costs,

$$TC_f = P(1 + g)^t \frac{g(1 + d)}{(1 + g)} I + P (1 + g)^{t-\frac{1}{2}} (Vhf) (F) + P (1 + g)^t \frac{rB}{L} I + \frac{P}{C} (1 + g)^{t-\frac{1}{2}} W$$

Simplifying, we get:

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

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 B.

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 Rs.290 per horsepower ex Karachi showroom and about Rs.220 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 Rs.310 per horsepower.^{6/} We will neglect any foreign exchange required to transport the tractor to the farmer.

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,

^{6/} At the official rate of exchange of the Rupee, this is equivalent to about U.S. \$ 65 per h.p., while the cost per h.p. is U.S. \$ 74 in Malaysia, and varies from U.S. \$ 81 to 110 in the United States [5, pp. 21, 22; 6, p.5_7.

etc. However, the importers are now bringing in implements for each tractor worth about 25% of the tractor's basic cost. Apparently this is adequate for the present conditions. Adding 25 per cent on to the basic cost of the tractors gives a total investment cost of about Rs.390 to the farmer, of which Rs.275 is in foreign exchange. Assuming that some savings can be made by local manufacturing, we will reduce the foreign exchange requirements to Rs.250 per horsepower. 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 studied the future of agricultural mechanization in West Pakistan recommend the purchase of implements whose total cost would approximately equal 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 Rs.620, of which about Rs.400 will be in foreign exchange.

^{7/} See [16, p.293; and 8, pp. 52-53].

One study estimates that the tractors should be used 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 costs 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 [27; 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; 28, 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 consumption should increase. Therefore, we will use a value of f of .067 gallons per horsepower hour.

^{8/} Another source [14, p.108] states that tractors operate 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.

The cost of the high speed diesel oil used in tractors is about Rs.2.12 to the farmer [16, p.294]. However, some of this cost is taken up by duties and taxes. After subtracting these the cost comes to about Rs.1.00 per gallon [13, p.31] which, according to our definition, is the financial cost to the nation. Out of this Rs.0.40 is the foreign exchange cost of imported crude oil [13, p.37].

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 [28, 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 [6, p.8]. A value suggested for use in the developing countries by another source is equivalent to an r of about 1.2 [27, p.68]. We will use a value of r equals 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 divided by 2 before being averaged with the r value for tractors

for use in our equation (II.iv). This gives a composite value of r equal to 1.00. This r will be used for computing the direct private financial costs as well as the direct financial costs to the nation. For foreign exchange costs, however, this figure is probably too high. Foreign exchange is spent for parts, materials, repair transport vehicles (especially mobile repair shops), tools, petrol for the repair of vehicles, etc. This may be about one third of the total repair costs. Since foreign exchange costs are two thirds of the total investment costs, we should use an r of 0.50 to compute the foreign exchange costs of repairs and maintenance.

Appropriate values for B (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 Rs.120 per month including all perquisites such as meals and clothes [16, 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 Rs.150 per month or Rs.1800 per year. We will also assume that the average tractor size will be 45 horsepower. However, in a labour surplus situation market wages do not measure the direct social costs which may be taken as zero. We will also assume that there are no foreign exchange costs involved.

Table II-1

Constants Used to Compute Direct Financial Costs

Constant	Units	Private Cost Calculation	Social Cost Calculation	Foreign Exchange Cost Calculation
P	horsepower	$.75 \times 10^6$	$.75 \times 10^6$	$.75 \times 10^6$
I	Rs./HP	620	620	400
r	-	1.00	1.00	0.50
L	Years	7.5	7.5	7.5
V	-	0.50	0.50	0.50
h	hours	800	800	800
f	gal/HP/hr	.067	.067	.067
F	Rs/gallon	2.12	1.00	0.40
W	Rs/Year	1800	0	0
C	HP/tractor	45	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 Cost Flows for different Growth Rates of Mechanization

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

Table II-3

Total Annual Direct Financial Cost at varying growth rates (g) of Tractor Horsepower

(Million Rupees; at Constant Prices)

Growth rate, g	Cost Measure	Year	1970	1975	1980	1985	1990
4 %	(a) Private	186	227	276	335	402	
	(b) Social	131	159	193	235	282	
	(c) Foreign Exchange	58	71	86	105	126	
12 %	(a) Private	249	440	775	1366	2408	
	(b) Social	187	330	582	1025	1807	
	(c) Foreign Exchange	91	161	284	501	882	
20 %	(a) Private	306	760	1894	4711	11742	
	(b) Social	239	594	1480	3681	9174	
	(c) Foreign Exchange	123	305	760	1890	4712	

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:

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

where P' is the constant total horsepower required, and other factors are as before.

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.5

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	1,605
Social	1,715	1,143
Foreign Exchange	773	515

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 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 Table I.4 and II.5 that annual direct costs exceed direct benefits. Towards the end of this paper, our tentative conclusions will be based mainly on the comparison of these direct cost-benefits flows. Before that we shall discuss some of the possible indirect costs and benefits of mechanization, which, however, are hard to quantify.

Section 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". [38, 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 the non-agricultural sector of West Pakistan. (The details about the projections are reported in Appendix C). Labour force in non-agricultural 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 non-agricultural labour force remains unchanged over the period.

Table III.1

Projections of Total, Non-Agricultural
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:				
Non-agricultural	7.0	8.5	15.9	4.2
Agricultural	8.9	10.0	13.3	1.9
Projection II:				
Non-agricultural	7.0	8.7	17.1	4.6
Agricultural	8.9	9.8	12.1	1.4

Source: See appendix C

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 millions in 1965 to 12 or 13.3 millions 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. In interviewing farmers in the Punjab who have mechanized, we received a remarkably consistent response that the labour force per acre had been reduced about fifty 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 requirements 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 are nearly 18 million acres and that 20 million acres would be susceptible 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

^{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 [36, p.153]. This study also found that while tractor power reduced permanent labour it stimulated demand for casual labour.

agricultural labour force in 1965. Estimates based on 1960 Agricultural Census data 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 in 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:

$$(III.i) \quad N_0' + E (N_t - N_0)$$

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:

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

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:

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

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:

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

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

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

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 non-agricultural 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^i we estimated to be 1.2 million. n^i 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^i we estimated to be about 20 million acres. P^i is .75 million horsepower and P^e 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^i 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 millions. If tractor horsepower would grow 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 Rs.5000 (See Appendix D). 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 non-agricultural sector would be at least around Rs.10,000.

Thus at a resettlement cost of about Rs.15,000 per worker, an additional investment of about Rs.10 billion 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 non-agricultural 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 Rs. 1 billion.

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 settled, because such resettlement would require much faster growth of the non-agricultural 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 ..." [20, p.54]. At the low prices which exist here it would appear, that commercial livestock production solely for the purpose of providing a meat supply would be of dubious profitability, even on land which has a low opportunity cost [see 44, 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 advantage 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.

SECTION 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.

Conclusions

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 Rs.330 million, and the direct benefits would be around Rs.200 million. Thus the net direct social cash flow in that year would be about minus Rs.130 million. 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 Rs.310 per h.p. and Rs.80 for implements, we can compute the annual direct social cost (including depreciation, and interest at ten per cent, maintenance, and operating costs of the tractors and implements) to be about Rs.175 per horsepower. The estimated social benefit from disposing of work animals has already been found to lie between Rs.110 and Rs.165. 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 of -- 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 lie in the significant divergence between social and private costs and benefits. First of all, we have evaluated the increased crop production resulting from mechanization at farm gate prices which would be in balance with the world market if Pakistan were to become an exporter of these commodities at the official exchange rate. In fact, internal prices are often above the world prices. Wheat, for example, is supported at a rate of Rs.15 per maund in the market. (In 1968 this was Rs.17). This would have to drop to about Rs.11 if Pakistan were to export wheat without subsidies or a change in the exchange rate. Furthermore, most of the previous analyses have compared mechanized agriculture with the traditional agriculture, whereas we have been comparing it with an agriculture based primarily on animal power, but using modern implements and techniques. Finally, the farmers find mechanization profitable because in addition to bullock elimination it reduces farm labour requirement and also allows them

to get rid of their tenant farmers. This is a benefit that accrues to the landlord, but not to society. Taking all these into account we estimated the direct benefits per h.p. to the farmer after paying wages are about double the social benefit or i.e., at least Rs.100 more than they are to society.

The individual can purchase tractors without duties or taxes being added. Furthermore the government will loan the farmer to make this purchase at an interest rate of $6\frac{1}{2}$ 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 Rs.200 per horsepower i.e., Rs.25 above social costs. 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 power demonstration and increased credit facilities, the small farmers will also soon adopt these new and improved cultural practices.

This package of inputs holds out really great promises. The fact that, unless large farms are mechanized now, the present rate of growth will soon taper off appears to be unfounded. Rather, the huge resources that will be required for such a mechanization programme will certainly tend to reduce resources available for 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 and other implements for cultural operations to be done better and faster.

We have considered in depth or detail the important problem of export markets for agricultural products. It is highly important to consider 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.

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Appendix A

The Cost of Draft Animal Power

Most of the writings on the benefits of mechanization begin with an analysis of the savings in cost which will be achieved if mechanical rather than animal power is used for certain agricultural operations. There have been some studies, mostly in India,^{1/} which have tried to measure these savings. But before one can measure reduction in costs, one must define what the costs are and how they should be measured. For mechanical power this is not difficult. We know the cost of importing the tractors and its implements. We know the costs of fuel which we have to pour into the machine every time we want it to do something. The first is clearly a fixed cost and the second, after adding repairs, maintenance, the driver's pay, etc., is clearly a variable cost.

But it is not so clear with animals. Often, nothing is paid for the animal because it is born on the farm, and nothing is paid for most of the food because the farmer grows that himself or the animal forages. Furthermore the amount of food consumed has little relationship to the amount of work done. If the animal is there, it eats whether it is to work or not. All this complicates the analysis; for if no money is paid, then what are the costs?

1/ For example Mathur and William [29].

In most of the literature this problem has been dealt with mainly in two ways. The first is to assume that nobody owns anything. Thus every time a farmer uses a bullock he has to rent it. One measures the rental price of bullocks in the rather small bullock rental market, assumes that conditions of perfect competition roughly exist to make this rental price equal to the marginal cost of producing a bullock, and takes this as the cost to the farmers of using bullocks. This approach is also supported by the economist's concept of "opportunity" costs, by which it is argued that if the farmer didn't use the bullocks himself he could rent them out, and therefore, by using them himself he is giving up the opportunity to earn the rental income. Thus the cost to the farmer is the income he foregoes by not renting out the bullocks.

The second approach, which also requires some implicit assumptions about perfect competition, is to determine the price at which animals are being sold and, again because the farmer is foregoing that income by not selling the bullock, *to take that as the capital cost of the bullock*. In this approach the value of food will typically be computed by multiplying the animals' consumption by the price of fodder. From here on the second approach is quite similar to the approach used for machinery. The food, along with maintenance, repairs, etc., is usually considered a

variable cost apparently on the reasoning that if fuel, which is food for the tractor, is a variable cost, then food, which is fuel for the animal, must also be a variable cost. There is the difficulty that this variable cost doesn't vary much in proportion to the amount of work done, but by treating it the same way as the fixed cost - that is by dividing the total annual cost by the number of hours the bullock works per year, one can calculate a hourly variable cost.

It is our contention that neither of these cost calculations is appropriate. There are, of course, various doubts about the extent to which the fodder, animal rental, and animal purchase markets actually satisfy the implied conditions of perfect competitions. The fallacies become more obvious, however, in the estimation of the savings resulting from partial mechanization. In such an estimation one typically compares the cost of doing various activities by mechanical power and animal power (using the hourly rates computed as described above) and concludes that the farmer will "save" so many rupees by using mechanical power for certain operations. But there is no actual saving. Partial mechanization does not reduce the number of bullocks the farmer has. Besides, should he hire a tractor to perform these various operations, he will only add to his cost the cost of renting the tractor. The apparent savings only occur because of a faulty costing methodology.

This, we believe, is the famous fuzzy thought on fodder feeding. There are no, or at least only quite minor, variable costs associated with the use of animal power. The only way to save the supposed costs is to get rid of the animals.

But if we agree that almost the entire cost of animal power is an economic fixed cost, we ought to go back to determine what that cost is. In our analysis we are concerned primarily with the cost to the nation - or, as it is often called, the social cost - and not with the costs to the farmer. For this reason we must investigate the question of whether the market prices truly represent the social costs. This first requires agreement on how the social cost can be measured. Let us consider this question for a moment.

To start at the beginning, a calf is born. Directly the calf cost nothing. Furthermore, since in Pakistan the female animal does not usually do any heavy work anyway, there has been no production foregone. However, she has been eating, and the calf can be charged with the value of the food she has consumed between her last calving and this one. The calf is then raised for a certain number of years before it is put to work. By this time the farmer has made an investment in the animal which is equivalent to the present value of all the foodstuffs it has consumed since being born plus that consumed by its mother plus

any other costs associated with keeping it alive. For the rest of its life the animal works. All the time it is working, it is consuming food and being maintained.

So the cost of an animal is the cost of raising it and keeping it alive, which cost is predominantly made up of the cost or value of the food it has consumed. To determine the investment in an animal one must, following the above analysis, compute the present worth of all past consumption less the animal's total product. Allocating this cost to the different working years of a bullock's life would be quite difficult - both conceptually and practically. It would be easier and as accurate to consider the annual cost of animal power to be equal to the annual cost of maintaining the entire animal population needed to perpetuate the required number of working animals in all future years.

Total animal population for
working bullock.

The structure of such a population can be estimated using techniques similar to those used by demographers in their theory of "stable population"^{2/}. However we will be able to use a considerably simplified form. The basic

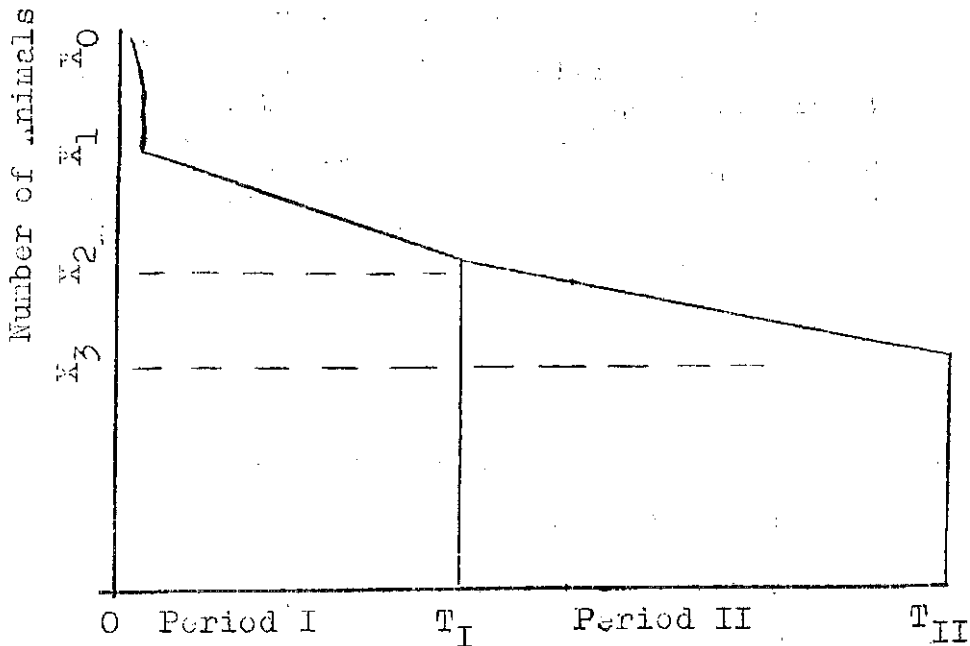
2/ The 'Stable population' is the foremost theoretical model of population processes. It is an extension of the stationary population model, and represents the permanent structure that a hypothetical population would ultimately have, if the assumed age specific birth rates and death rates persisted without change. It is derived completely from these birth rates and death rates, is closed against migration, and is not dependent on the composition of any concrete population

[See 1, p. 133]

question can be derived by the help of figure A-1 which shows the generalized life history of all the animals born in year 0. Of X_0 births, only a certain proportion will be males. All these will be kept, along with enough females to reproduce the female population. The total of these two groups is X_1 , and $X_0 - X_1$ animals are killed or raised for meat.

What happens to these animals does not concern us since we are only interested in the population required for the working force. Those animals that are raised for a certain number

Figure A-1



of years, until T_I , before they are put to work. Some of them also die during this period so that at the start of working period, Period II, there are only X_2

animals left. The survival rate for period I, S_I is $\frac{X_2}{X_1}$. Similarly, some die off during the working period, and the survival rate for Period II, S_{II} , is $\frac{X_3}{X_2}$. At the end of this period, i.e. on completion of T_{II} years all the remaining animals are killed off.

Let us first construct a model in which the population is stationary. We can then estimate from the model the total animal population required to maintain one working bullock. The required total population will vary under different conditions in regard to birth rate, young age, working age, reproductive age, survival rates etc. In our simplified but general model different values for these parameters can be incorporated to obtain estimates under different sets of conditions. The model is restrictive in so far as the assumed growth rate is zero.

Let

P = Total cattle population required

B_y = Young bullocks

B_w = Working bullocks

F_y = Young females

F_r = Reproductive females

b = Number of births per reproductive female per year

α = Probability of a male calf being born

B_b = Number of males born in a year

0 to $T_I - 1$ (in completed years) = Young age of males and females.

T_I to $T_{II}-1$ (in completed years) = Working age of bullocks and reproductive age of females.

T_{II} (in completed years) = Age of being killed off.

S_I = Survival rate of males and females from age 0 to age T_I years.

S_{II} = Survival rate of males and females from age T_I to age T_{II} years.

The

$$(A1) B_b = F_r \eta^b$$

$$(A2) B_y = B_b \sum_{t=0}^{T_I-1} S_I \frac{t}{T_I}$$

$$(A3) B_w = B_b S_I \sum_{t=T_I}^{T_{II}-1} S_{II} \frac{t-T_I}{T_{II}-T_I}$$

$$(A4) F_r = \frac{B_b}{\eta^b}$$

Since under our identical assumptions about survival rates, and young and working ages of males and females

$$\frac{F_y}{F_r} = \frac{B_y}{B_w}$$

$$(A5) F_y = \frac{B_b}{\eta^b} \cdot \frac{B_y}{B_w} = \frac{B_b}{\eta^b} \cdot \frac{B_b \sum_{t=0}^{T_I-1} S_I \frac{t}{T_I}}{B_b \cdot S_I \sum_{t=T_I}^{T_{II}-1} S_{II} \frac{t-T_I}{T_{II}-T_I}}$$

$$(A6) P = B_w + B_y + F_r + F_y$$

Dividing both sides by B_w , we get

$$(A7) \frac{P}{B_w} = 1 + \frac{B_y}{B_w} + \frac{F_r}{B_w} + \frac{F_y}{B_w}$$

$$\text{Let } \Omega I = \sum_{t=0}^{T_I-1} S_I \frac{t}{T_I}$$

$$\text{and } \Omega II = \sum_{t=T_I}^{T_{II}-1} S_{II} \frac{t - T_I}{T_{II} - T_I}$$

Then

$$(A7) \frac{P}{B_w} = 1 + \frac{B_b \Omega I}{B_b b_I \Omega II} + \frac{B_b}{\eta^b B_b S_I \Omega II} + \frac{B_b \Omega I}{\eta^b B_b S_I \Omega II} + \frac{1}{B_b S_I \Omega II}$$

$$= 1 + \frac{\Omega I}{S_I \Omega II} + \frac{1}{\eta^b S_I \Omega II} + \frac{1}{\eta^b S_I \Omega II} \cdot \frac{\Omega I}{\Omega II}$$

This expression gives the total population required per working animal if the bullock population remains stationary.

When S_I and S_{II} are both less than 1, as is likely it can be shown that

$$(A8) \Omega I = \sum_{t=0}^{T_I-1} S_I \frac{t}{T_I} = \frac{1 - S_I}{\frac{1}{T_I}} \cdot \frac{1}{1 - S_I}$$

Similarly

$$(A9) \quad II = \frac{t - T_I}{T_{II} - T_I} S_{II} = \frac{1 - S_{II}}{1 - S_{II}}$$

When a bullock population is growing at an annual compound rate ω , the effect of this growth rate on each age interval of the stationary population is expressed as $e^{-\omega a}$ where: e is the base in the system of natural logarithms, and a is the mid-point of each age interval (adopted as the approximate average age of the age group) [1, p. 218_7]. The mid-point is $(x + \frac{n}{2})$, that is, age x plus one-half of the number of years, n , included in the interval. For example when the age interval is 0 to 1 year, the mid-point is 0.5 year, for 1 to 2 years it is 1.5 years and so on.

The effect of the growth rate is calculated by multiplying each single year age group in the stationary population by the corresponding value of $e^{-\omega (x + \frac{n}{2})}$. When this is done, we can construct a more general model of cattle population. It can be shown that in this general case also the expression for $\frac{P}{B_w}$ is the same as shown in (A7) above, but in this case if S_I and S_{II} are

both less than 1, as is likely

$$\Omega_I = \sum_{t=0}^{T_I-1} S_I \frac{t}{T_I} e^{-(t+\frac{1}{2})}$$

$$= \frac{e^{-0.5} - S_I e^{-(T_I + 0.5)}}{1 - S_I} \frac{1}{T_I} e^{-\dots}$$

and $\Omega_{II} = \sum_{t=T_I}^{T_{II}-1} S_{II} \frac{t-T_I}{T_{II}-T_I} e^{-(t+\frac{1}{2})}$

$$= \frac{e^{-(T_I + 0.5)} - S_{II} e^{-(T_{II} + 0.5)}}{1 - S_{II}} \frac{1}{T_{II} - T_I} e^{-\dots}$$

Now multiplying the population of each group per bullock by its relative consumption we can estimate the total fodder consumption by the animal population to maintain one working bullock. If b_w , f_r , f_y , and b_y are respectively the fodder consumption (in "livestock units") of the working bullock, the fertile female, the young female and the young male then we can have the following general expression for δ - the total fodder consumption by the animal population to maintain one working bullock:

$$(A10) \quad \delta = 1. \delta_{b_w} + \frac{\Omega_I}{S_I \Omega_{II}} \delta_{by} + \frac{1}{S_I \Omega_{II}} \delta_{fr} + \frac{1}{\eta_b S_I \Omega_{II}} \delta_{fy}$$

We made it clear earlier that given the values of other parameters, the values of Ω_I and Ω_{II} will depend on the growth rate δ , whether it is zero or more than zero.

Although there is very little known about the livestock sector in Pakistan, there have been couple of recent studies which will help us attach numbers to our constants. The Indus Special Study found that under the present conditions, bullocks do not begin to work until they are three, sometimes four years old, and then continue to work for about 8 years [16, p.282]. Therefore we will take T_I as 12 years. They also found the average inter-calving period of reproductive females to be between 12 and 18 months [14, p.111]. If we take 15 months as the average, this is equivalent to a general fertility rate of $1000\eta = 800$, i.e. 800 per 1000 F_r or .8 per F_r . Values of δ_{b_w} , δ_{by} , δ_{fr} and δ_{fy} in "livestock units" are given as follows:

Table A-1

Livestock Units for Bullocks

		Livestock units
Adult males	♂ bw	1.00
Young males	♂ by	0.77
Adult females	♀ fr	0.77
Young females	♀ fy	0.74

[Source 16, o, 303]

The growth rate of the bullock population is unknown. Official estimates of the growth rate of the entire livestock sector are about 1.9 per cent, and another estimate by the Planning Commission was 2.7 per cent; but a more recent study has come up with a value of 4.5 per cent [10, p. 490]. We might expect the growth rate for the population of draft animals to be similar to that for cropped acreage, although there is reported to be substantial under-employment of these animals [16, p. 278; 14, p. 110]. Cropped acreage from 1958/59 to 1966-67 has been growing at a rate of about 2.5 per cent per year. Production has been increasing faster, but some of this increase has been (and more will continue to be) a result of increased yields. It is unlikely that total cropped acreage would grow any faster than 2 per cent over any extended period of time. Therefore we might take this as a reasonable

growth rate for the bullock population, although we will carry out computations for 2.5 per cent as well.

Using these parameters the solutions for our several stable populations models are as given in Table A-II.

Table A-II

Derivations of Ω_I , Ω_{II} , $\frac{B_Y}{B_W}$, $\frac{F_r}{B_W}$, $\frac{F_Y}{B_W}$
and δ for a few different values of
the parameters

($b = .8$ and $\eta = .5$ in all cases).

σ	S_I	S_{II}	T_I	T_{II}	Ω_I	Ω_{II}	$\frac{B_Y}{B_W}$	$\frac{F_r}{B_W}$	$\frac{F_Y}{B_W}$	δ
0	.9	.9	3	11	2.899	7.692	.419	.361	.151	1.71
0	.8	.9	3	11	2.789	7.692	.453	.406	.184	1.80
0	.9	.9	4	12	3.846	7.692	.556	.361	.201	1.85
0	.8	.9	4	12	3.704	7.692	.602	.406	.245	1.96
2%	.9	.9	3	11	2.815	6.666	.469	.417	.196	1.83
2%	.8	.9	3	11	2.709	6.666	.508	.469	.238	1.93
2%	.9	.9	4	12	3.698	6.534	.629	.425	.267	2.01
2%	.8	.9	4	12	3.561	6.534	.681	.478	.326	2.13
2.5%	.9	.9	3	11	2.794	6.432	.483	.432	.209	1.86
2.5%	.8	.9	3	11	2.691	6.432	.523	.486	.254	1.97
2.5%	.9	.9	4	12	3.666	6.275	.649	.433	.288	2.05
2.5%	.8	.9	4	12	3.523	6.275	.702	.498	.350	2.18

In comparison to these computed results, we can look at ~~the~~ actual result of livestock censuses. Probably the most recent was done on 20 watercourses spread through the Punjab and find [16, Chapter 12_7. The average ratio of F_r / B_w (assuming their definitions correspond to ours) was 0.30, the average ratio B_y / B_w was also 0.30 and the average ratio F_y / B_w was 0.08. Their computed $\bar{\delta}$ was about 1.52 [16, pp. 304, 305_7. These ratios are lower than any given in Table II-II. However they also report that "only about 30 per cent of the draft animals were bred and raised on the farms they were at present working [16, p.282_7. Unfortunately they have given no details on the distribution of the sources from which the other 70 per cent are purchased. If they are usually purchased from other farms in the same area, it should not affect our calculations since we are taking averages over an area. Apparently there is at least some interfarm exchange [14, p.111_7. On the other hand, if the animals are raised elsewhere and imported into the farming areas, then the total population per working bullock is higher than indicated by the survey figures. This may be ^{the} ~~the~~ case. Since we cannot be sure that the survey data present the information we require, we will use the estimates from our stable population models in further computations.

Gross social cost of Maintaining Bullocks

after computing the number of livestock units per working bullock required to maintain the working animal population, we have to estimate the value of the resources consumed per year by these livestock units. A common measure of livestock feed is the number of total digestible nutrients (TDN) it contains. The survey referred to above covering 20 watercourses found an average of about 3,800 lbs. of TDN fed per year per livestock unit [16, p.308] although variations from this average were quite high—the maximum watercourse average was a reported 8,300 lbs. TDN per year per livestock unit, and the minimum was 2,600 [16, p. 309]. The composition of this total amount is shown in Table A-III.

Table A-III
Composition of Livestock feed

Foodstuff	Lbs.TDN per lb. Foodstuff	Percentage of total TDN supplied by Foodstuff.	Cross Weight Foodstuff consumed per livestock Unit lbs.
	(1)	(2)	(3)
Rabi Fodder	.11)	70.3% ^{a)}	19,800
Kharif Fodder	.16)		
Sugarcane Tops	.13	1.2%(8.2) ^{b)}	350 (2400) ^{b)}
Wheat Bhusa	.48	17.3%	1,370
Concentrates	.75	0.7%	670
Plant Residues	.05	1.9%	1,440
Cash Crops	.20	2.0%	380

Source: Column 1 [16, p.309] / Column 2 [16, p.311]
Column 3 was calculated from other two columns.

Notes: a) 68.9 per cent of this was fed as green fodder and the remaining 1.4 per cent as grams fodder.

contd.....

b) Survey was not underway during sugarcane harvesting season so the figure in parentheses was computed from the amount of tops available.

The organization making this survey computed the cost of these foodstuffs by using market prices as follows:

Table IV
Feeding Costs per Pair of Bullocks

<u>Item</u>	<u>Cost</u>
1.50 acres of green fodder @ Rs. 260 per acre	390
110 maunds of wheat bhusa @ Rs. 3.50 per maund	384
3.50 maunds of grams (concentrate) @ Rs.17 per maund	60
	<hr/>
	Rs. 834
	<hr/>

Source: 16, p. 287.

However this does not necessarily represent the social cost of these foodstuffs. To determine this cost, we have to consider what the opportunity cost is of the resources which go into their production. Here we have the immediate problem of deciding whether we should consider their opportunity cost only outside the livestock sector, or also consider their value when fed to other animals. The Indus Special Study found that the average value per lb. of TDN fed to milch cattle was about Rs. 0.13. However, the marginal value was probably much below this. This conclusion is supported by the fact

that the market price of fodder was found to be only about Rs. 0.09 per lb. of TDN.

It would be inappropriate to use the Rs. 0.13 per lb. figure as the value of animal foodstuffs transferred from draft animals to other animals. Nor should we use the Rs. 0.09 per lb. figure even assuming that it does represent the true present marginal value of animal foodstuffs, unless it was demonstrated that the marginal revenue product curve is horizontal which is quite unlikely. Transportation problems combined with presently limited markets make it unlikely that any amount of additional productions of milk and meat could be absorbed at the present price. For this reason we prefer to consider the value of the foodstuffs in alternative uses outside the livestock sector as their appropriate social cost.

For such items as grazing (which was not included in the Indus Special Study computations) and plant residues this value is obviously very low. The only apparent alternative use of these items is green manure. Their economic contribution in such a use would be so slight that we can safely disregard it. Wheat and rice bhusa, the straw left over after the grain is thrashed, presently also has little value outside the livestock sector. It could be used as a sort of "green manure", or probably more profitably as a raw material for paper making. It is unlikely that in the near future paper plants could

possibly use all of the bhusa production in West Pakistan. Also, there is most likely a certain distance from any factory beyond which it would be uneconomical to collect the bhusa. The transport costs would probably exceed the value of the straw as a raw material. We know of no studies which has been undertaken on this subject although it is obviously of great importance if, in fact, mechanization is to be a major agricultural policy. Therefore, we will arbitrarily assume that the bhusa fed to the cattle on the farm has an economic cost of Rs. 1.00 per maund. Similarly sugarcane tops have minimal alternative use outside the livestock sector and we shall assign them no value.

Some concentrates may have real opportunity cost, others probably not. For instance, an important concentrate is oilseed cake for which there is an international market. However, it does not appear as if Pakistan could profitably enter into this trade since the cost of transportation from the Punjab to Karachi is nearly the same as the world market price for the commodity. The same is true for gram processing operations. Therefore, we might value the total concentrates at an arbitrary Rs. 2.0 per maund. Cash crops, of course, do have some value. Pakistan has particularly been faced with a shortage over the past several years. However, this situation is rapidly changing, and it appears as if any additional foodgrains will have to be exported. In this

case the farm gate value would probably drop to below Rs. 9 per maund. We will take Rs. 10 a maund for our purposes.

This leaves the fodder crops. One of the major advantages claimed for mechanization is that it would allow land and other resources now used for fodder to be transferred to the production of other valuable crops. The primary resources which presently go into the production of fodder are land, water, manual labour, and bullock power. Fertilization of fodder crops is apparently becoming more common although the average level is still very low [16, p. 394]. Of these resources, we can consider fertilizer and water as being the only two that have any real social cost since labour inputs can be scheduled to occur at times when there is little alternative employment. We have already established that the cost of the animal power is the cost of the fodder so we would be going in a circle if we argued that the cost of the fodder is partially composed of the cost of the animal power. The appropriate way of treating this problem is to consider the resources that go into the fodder to feed the bullock population as the cost of the working animals, and to take the output of this sector as the amount of the work the bullocks can do on other crops or fodder for non-draft animals. The work the bullocks do in raising their own feed is an intra-sectoral intermediate good, and is appropriately

neglected in our computations.

Land, in most of West Pakistan, is a resource which ^{has} almost no economic value unless water is available for irrigation. The World Bank and the Indus Special Study groups have computed that even under greatly increased - almost full - development of the available water resources the irrigated acreage cannot be increased significantly, and the cropping intensity will be limited to about 150 per cent because of a shortage of water [17, p.14; 18, pp,27,42_7. The unirrigated acreage can raise little of economic value.

However, fodder does require water. Calculations of the total annual water requirements for various crops in the Lower Rechna Doab, based on calculations using the Balaney-Griddle formula, are given in Table A-V.

Table A-V
Water Requirements of Crops - Lower Rechna Doab

Crop	<u>Kharif</u>	Acre feet of water required per acre of crop.	Crop	<u>Rabi</u>	Acre Feet of water required per acre of crop.
Rice		3.43	Wheat		1.35
Sugarcane		4.40	Sugarcane		1.37
Cotton		2.70	Pulses		1.14
Maize		1.73	Oilseeds		1.04
Millet		1.41	Vegetables		0.98
Vegetables		2.02	Fruits		1.36
Fruits		2.64	Misc. Other		
Miscellaneous,			Crops		1.12
Other crops		2.45	Rabi Fodder		2.15
Kharif Fodder		3.02			

(Source: 39, Appendix D_7)

Making only a quick general analysis of these data, it would appear as if in the Kharif season, for instance, a farmer could plant about 1.12 acres of cotton, 1.50 acres of vegetables, or .88 acres of rice for every acre of Kharif fodder eliminated. Similarly in Rabi season, he could plant 1.60 acres of wheat, 2.19 acres of vegetables, or about 2.0 acres of oilseeds for every acre of Rabi fodder eliminated.

These ratios actually understate the potential trade-offs since rainfall accounts for part of the water requirements and the more acreage is planted the more rainfall will contribute to crop production. Considering this aspect, and defining the Kharif season as extending from mid April until mid October and the Rabi season as composing the rest of the year, the average effective rainfall per acre is about 6.21 inches during the Kharif season and about 1.1 inches during the Rabi season [39, Table D-7]. Therefore, if we were to, say, substitute cotton for Kharif fodder, the net irrigation requirement for cotton 2.18 acre feet per acre and the irrigation water given up by the fodder would be 2.50 acre feet per acre. Thus we could get about 1.15 acres of cotton rather than the 1.12 acres we calculated originally. For crops like rice and

sugarcane which require more water than the Kharif fodder, this adjustment would work in the opposite direction reducing the ratio of the alternative crop acreage to the fodder crop acreage. In any case the adjustment would usually not be very large, particularly for the most likely substituting crops.

To simplify our further calculations, let us assume that 50 per cent of the eliminated Kharif fodder would be switched to cotton and 50 per cent to rice, and that all the Rabi fodder would be replaced by wheat. Thus for every acre of Rabi fodder we would get about 1.6 acres of wheat. The value of these alternative crops depends on their yield, the market price, and the cost of input.

Presently cotton is competitive with the world market price and has a farm gate value of about Rs. 32 per maund of seed cotton [16, p. 328]. The average yield of American cotton found in the Indus Special Study on 20 watercourses was about 5.6 maunds of seed cotton per acre [16, p. 153]. Thus the total value was about Rs. 180 per acre. The Indus Special Study computed the total variable cost per acre to be Rs. 43.85. However, much of this was for labour which we will take as having no social cost, and only about Rs. 5 worth of fertilizer were applied per acre. Let us assume that the value of cotton acreage then is about Rs. 1.75.

The average yield of rice is about 21 maunds of paddy per acre [16, p. 156]. The value depends upon the type of rice grown. For Basmati rice Pakistan receives about 120.00 per ton or about Rs. 50 per maund for clean whole rice. However, the present milling process results in about 50 per cent broken from Basmati rice [7, p. 8]. Much of this is probably induced by the present pricing system under which whole milled rice is produced at Rs. 30 per maund by the government for export whereas one third of the brokens can be kept by the mill and sold on the local market at prices exceeding Rs. 100/^{per}maund. Let us assume that this breakage could be reduced to 20 per cent [7.p.12], that local prices would fall into line with world market prices, and that brokens would be valued at about Rs. 30 per maund. This would result in an average price of milled rice at Rs. 46 per maund. Since about two thirds of the paddy ends up as milled rice, this would make the value of paddy about Rs. 31 per maund. Subtracting about Rs. 3 per maund for transportation, etc., we will assume the value of paddy is Rs. 28 per maund or Rs. 588 per acre at the farm gate. Again, the present social costs are low, unless some cost is to be placed on the relatively skilled labour used in transplanting [16, p. 158]. We will assume that the net social value per acre is Rs. 580.

This is assuming that fodder land would be switched over to Basmati rather than some other type of rice. At present only about one fourth of the

rice acreage is under Basmati [11, Table A-3]. The value of coarse and medium rice in international trade is about 30% of that for Basmati. Therefore, assuming that about one third of the released land would go to Basmati and the rest to other less valuable varieties, the average value per acre of rice would be about Rs. 310. Assuming that fifty per cent of the Kharif fodder water was transferred to cotton and fifty per cent to rice, the average net soil value per acre transferred would be about Rs. 240.

Turning now to rabi fodder, the average yield of wheat found by the Indus Special Study was about 13 maunds [16, p.181]. For the past few years the price of this wheat has been quite high in Pakistan because of bad harvests. Let us, therefore, take the value of wheat as what it would have cost (at the official exchange rate) to import it. The average world market price of wheat from 1959 to 1964 was Rs. 13.2 per maund [45]. The cost of transporting this wheat to the cities is probably about the same as processing and transporting it from the farm to the cities. Therefore we will take this as the social value per maund, giving a gross value of about Rs. 170 per acre of irrigated wheat. Again, the social costs of production have been low [16, p. 395] so we will adopt a net value of Rs. 165 per acre. Thus for every

acre of Rabi fodder given up, about Rs. 165 x 1.6 i.e., ^{Rs.265/-} will be gained in wheat according to these calculations.

These computations have been necessarily crude. we have not taken account of the fact that at present some crop yields are probably reduced somewhat as a result of intercropping with fodder, nor that wheat yields are generally higher if the wheat follows fodder than if it follows rice or cotton. There are an infinite number of such improvements which could and should be made. However, of more importance is the fact that these computations pertaining to the past do not accurately reflect future conditions. Crop yields in Pakistan are increasing - most spectacularly in wheat and rice at present, but other crops can be expected to follow suit. However, fodder yields can also be expected to increase meaning that less land will be required to provide the same amount of animal feed. If the yield of all crops increased at the same rate, the trade-off values we have calculated would not change much. The effect of differential yield increases would be difficult to predict. Therefore, as a first approximation, we will only make some arbitrary adjustment in our calculations. The annual cost of two acres of fodder crop we have calculated to be Rs. 505 (one acre Kharif plus one acre of Rabi). Let us raise this by about 20% up to Rs. 600. This is somewhat above the present market price [see 16 p.287].

To convert this into the cost per working animal, we have to first find out the number of acres of fodder raised per livestock unit. The Indus Special Study found this to average 0.63 acres a year [16, p.65]. In another part of this study they found that "the number of [Livestock] units per acre was highest on the < 5 acres farms, viz. about 3, and lowest on the 25 acre and over farms, viz. 1.75" [19, p. 38], but they also found that the farmers would have liked to increase their fodder acreage to an average level of 1.1 to 1.5 livestock units per acre. [19, p. 38]. However, we will assume that the farmers will not in fact do this because of the opportunity costs of the additional resources such an expansion would require. We will therefore assume that a factor of 0.6 acres of fodder per year per livestock unit will continue. Thus fodder has a social cost of Rs. 180 per livestock unit. Adding this to the cost of the other foodstuffs and including Rs. 50 for other expenses, we have a total cost of about Rs. 300 per livestock unit as shown in Table A-VI.

Table VI.

Total Social Cost per Livestock Unit.

Item	Amount consumed maunds	Value Rs.
Podder	246.5	180
Bhusa	25.4	25
Concentrates	0.4	2
Plant Residues	17.9	0
Sugarcane Tops	4.4	0
Cash Crops	4.7	47
Other Expenses	-	50
		<u>Rs. 304</u>

(or Rs. 300 roughly)

This is equivalent to about Rs. 270 per livestock unit under the present conditions.

Social Benefits

On the other hand there are certain benefits of raising work animals, and these should be deducted from the cost computed above to determine the net cost of draft animals. These benefits include the value of the hides, meat, bones, horns and hooves, manures, and the milk of the cows. Unfortunately we do not have a great deal of information which can be used to evaluate the products. The selling price of the animals after they have finished their working life is reported to

vary from Rs. 25 to Rs. 100 with Rs. 50 being about average [16, p. 317; 14, p.111]. Whether this actually represents the social value of these animals, or in fact exactly what happens to them after they are sold, is not clear. Hides, leather, and leather goods are important exports from west Pakistan as are bones, horns, and hooves. Much of the meat delivered to the cities probably comes from such animals. However having no way to estimate the contribution of the farmers' worn out bullocks and supporting cows to these purposes, one can only assume that Rs. 50 per animal is a fair representation of their social value.

About 50% of the adult females were found by the Indus Special Study to ^{be} in milk at any time, and the average annual production for a cow in milk is 248 pounds [16, p. 316]. Therefore there are about 125 lbs. of milk produced annually per adult female. This is mostly sold at the village for Rs. 0.50 per seer to a vendor who transports it to a city [16, p. 340]. Thus average value of milk production per adult female animal is about Rs. 30 per year.

Each animal produces, according to one estimate about 30 pounds of fresh dung a day [37, p. 128]. Approximately one fourth is used as fuel, and the rest as manure [16, p. 318]. In addition, much of the urine is passed out in the fields and thus serves as fertilizer. The amount of fertilizer contained in

one ton of manure is 9 lbs. of Nitrogen, 3 lbs of available P_2O_5 and 3 lbs. of available K_2O [21, p. 127_7]. All these nutrients presently sell at a government subsidized rate of Rs. 0.50 per pound in the form of chemical fertilizers. The rate of subsidy is supposed to be about 35 per cent. This indicates that the total value of these nutrients is about Rs. 10.00 per ton of manure but we assume it to be as low as Rs. 2.50 per ton (The value of the marginal physical product of these nutrients is clearly much greater than this). The organic matter in the manure and the urine also have some value, but we have no information by which to calculate these. Therefore, we will arbitrarily raise the value of the manure per ton to Rs. 3.00 (This compares to a market price of 5 to 6 rupces per ton). Taking the output of 30 lbs. per day to apply to a livestock unit, we get a minimum value of about Rs. 11.00 per year per livestock unit for the 75% of the manure used for fertilizing.

For the other 25 per cent used for fuel, one ton of dried dung has been found to be equivalent to 0.4 tons of coal or 0.06 tons of kerosene [21, p. 62_7]. About 70 per cent of fresh dung is water [37, p. 127_7], and in the drying process most of this is lost - leaving, let us say 40 per cent of the original weight. This would mean

that approximately one half ton of dried dung, which is equivalent to 0.2 tons of coal or 0.03 tons of kerosene, is used for fuel per livestock unit per year. Kerosene, though it sells for more in the market, should actually cost somewhat less than light diesel fuel. The latter has been estimated to cost about Rs. 0.91 per gallon after eliminating all taxes [7, p.377]. Therefore let us assume that kerosene costs about Rs. 0.85 paisa per gallon or Rs. 0.10 paisa per lb. By this measure the value of the dung burned as fuel per year would be about Rs. 6.60 per livestock unit. Probably not all of the old dung would be replaced by kerosene, so we might take a fuel value of Rs. 4 per livestock unit per year.

Taking into account all of the above factors, and using the formula developed previously for the stable population parameters, we can express the benefit (in Rupees) produced by the total animal population required to support one work animal as follows:

$$\begin{aligned}
 \text{Value of dung: } & 15 \\
 \text{Value of milk: } & 30 \frac{F_r}{B_w} = \frac{30}{\eta_b S_I \Omega_{II}} \\
 \text{Value of Meat, hides, etc: } & \frac{50 S_{II} e^{-(T_{II}+0.5)}}{\Omega_{II}} \left(1 + \frac{1}{\eta_b S_I \Omega_{II}} \right)
 \end{aligned}$$

This last expression is derived in the following manner.

The proportion of worn out bullocks of (age T_{II}) per working bullock is

$$\frac{B_b \cdot S_I \cdot S_{II} \cdot e^{-(T_{II}+0.5)} \omega}{B_w} = \frac{B_b \cdot S_I \cdot S_{II} \cdot e^{-(T_{II}+0.5)} \omega}{B_b \cdot S_I \cdot \Omega_{II}} = \text{say}(K)$$

This is also the ratio of worn out females to adult females. Therefore worn out animals per working bullock is :

$$\begin{aligned} &= K \left(1 + \frac{F_r}{B_w} \right) \\ &= \frac{B_b \cdot S_I \cdot S_{II} \cdot e^{-(T_{II}+0.5)} \omega}{B_b \cdot S_I \cdot \Omega_{II}} \left(1 + \frac{1}{\eta_b \cdot S_I \cdot \Omega_{II}} \right) \\ &= \frac{S_{II} \cdot e^{-(T_{II}+0.5)} \omega}{\Omega_{II}} \left(1 + \frac{1}{\eta_b \cdot S_I \cdot \Omega_{II}} \right) \end{aligned}$$

Net Social Cost of Bullocks

Combining our estimates of cost and benefit of the animal population with the results of our computations for the stable animal population, we can compute the costs of society per working bullock. The results of some such computations are given in Table A-VII.

Social Cost per Draft animal under different values of the Parameters. (b = .8 and $\gamma = .5$ in all cases)

	T _I = 3		T _{II} = 11				T _I = 4 and T _{II} = 12			
	0	0	2%	2%	2.5%	2.5%	2%	2%	2.5%	2.5%
SI	.9	.8	.9	.8	.9	.8	.9	.8	.9	.8
SII	.9	.9	.9	.9	.9	.9	.9	.9	.9	.9
Gross Cost (Rs/Year)	510	540	550	580	560	590	600	640	615	655
Less Benefit (Rs/Year) from:										
Dung	26	27	28	29	28	30	30	32	31	33
Milk	11	12	13	14	13	15	13	14	13	15
Meat etc.	8	9	10	10	10	10	10	10	10	10
Net Cost (Rs/Year)	465	493	499	537	509	535	547	584	561	597

Note: Computations are based on estimates shown in Tables I-II and V-VI, and formulas for estimating values of Dung, Milk and Meat etc., stated earlier.

It would appear as if the social cost of maintaining an animal population is from Rs. 450 to Rs. 600 per working animal per year. One conclusion that we can draw from these results is that we need not have bothered since the cost computed for a pair of bullock using the more traditional type of calculation is about Rs. 970 [16, p. 288] or Rs. 485 per bullock per year. However, one advantage this method does have beyond confirming the rationality of the West Pakistani farmer is that it allows the direct computation of the cost reductions which would result from such improvements as longer life span, earlier working ages, etc., as are discussed in the text of this article.

One important and rather dubious assumption implicit in the calculations is that Pakistan will have an unlimited export market for her agricultural products at the present prices. It is not at all clear that this can be expected to be the case. One outcome of the "Kennedy Round" trade agreement was, in fact, to restrict the amount of wheat that surplus countries could sell on the world market. Of the deficit countries, Pakistan and India have been among the largest importers and both should soon reach self sufficiency. The same is true of rice. The market for Basmati appears at present to be limited, and the same developments which are permitting such a rapid breakthrough in coarser varieties of rice in Pakistan are also available, as they are with wheat, to every

other country. In cotton Pakistan's share of the world market is small enough that it should be relatively easy to increase exports. But it would be foolish and perhaps very costly, for Pakistan to presume that unlimited markets will exist for basic agricultural commodities. This is another aspect of the mechanization question which deserves very careful investigation.

Foreign Exchange Costs of Maintaining
Bullocks

Assuming for now that such markets will exist, we can calculate the foreign exchange costs of maintaining bullocks. The price we have assumed for wheat is its world market price, C.&F. Pakistan's foreign exchange earnings would be less than this by the cost of shipping. The FOB price Karachi should be about Rupees 10.5 per maund [45_7]. The export price of Basmati rice is about Rupees 50 per maund and that of medium and coarse rice about Rupees 15 per maund [45_7]. The export value of seed cotton is about Rupees 36 per maund [45_7]. Part of these values should be attributed to the value added to the commodity by transportation, packing, ginning, etc., after it leaves the farm. We, however, will consider it all to be foreign exchange earnings attributable to mechanization. On this basis the foreign exchange opportunity cost of fodder and other items per livestock unit can be computed as we computed the social costs in Table A-VI. This foreign exchange cost per livestock unit comes to Rs. 275 as is shown in Table A-VIII.

Table A-VIII

Foreign Exchange Costs per Livestock Unit
(In Rupees per year)

<u>Item</u>	<u>Foreign Exchange Opportunity Cost</u>
Fodder	200
Bhusa	25
Concentrates	2
Cash Crops	47
	<u>274</u>

Of those items produced by the animal sector having an economic value, the dung (both for fuel and fertilizer) and part, say one fourth, of the value of the retired animal, would have an opportunity cost in foreign exchange. On this basis, we can compute the total net foreign exchange cost of animal draft power as we computed the social costs in Table A-VII. The results of a few computations are given below in Table A-IX.

Table A-IX

Foreign Exchange Opportunity Cost per Draft Animal
(Rupees per year)

	1.71	1.80	1.93	1.97	2.05	2.18
Gross Costs (Rupees)	469	493	500	537	562	597
Less Rupees: Roughly estimated value of total animal product in foreign exchange.	20	25	25	25	25	25
<u>Net Costs (Rupees)</u>	<u>449</u>	<u>468</u>	<u>475</u>	<u>512</u>	<u>537</u>	<u>572</u>

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Thus it would appear that the foreign exchange opportunity cost per draft animal is between Rs. 450 and Rs. 625, while for a stationary population it is between Rs. 450 and Rs. 470.

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Appendix B

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 that 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 operating tractors during year $t + 1$ and assuming one driver for each tractor, the number of drivers required would be:

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

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

$$\frac{P}{C_m} (1 + g)^t \left[g(1 + d_g) I + (1+g) \frac{rB}{L} I + (1+g)^{\frac{1}{2}} (V_{hf}) F \right].$$

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 months 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, 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 calculation

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 B-1.

Table B-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 C.

Projections of Labour Force in Agricultural
and Non-Agricultural Sectors in West Pakistan
(1965-1985)

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 non-agricultural labour force as briefly explained here. The projections of labour force in the non-agricultural sector are based on the expected growth of output and labour productivity in that sector.

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

	<u>Million Rupees; at 1964/65 market price</u>				
	1965	1970	1975	1980	1985
IGNP	45,540	62,765	89,185	129,690	187,300

If, however, we use the Planning Commission 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:

	<u>Million Rupees; at 1964/65 market prices</u>				
	1964/65	1969/70	1974/75	1979/80	1984/85
IIGNP	43,428	59,576	83,966	121,520	173,912

The difference arises partly from the use of calendar years in series I and fiscal years in series II, and partly from the non-allocation 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% to West Pakistan and 40% to East Pakistan; for 1975, 1980, 1985 - 50% to West Pakistan and 50% to East Pakistan. This gives the projection of West Pakistan's GPP as shown in Table C-I. 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 C-I

Projection of West Pakistan's Gross Provincial Product, and the share of Agriculture and Non-Agriculture (1965-1985) Million Rupees at 1964/65 Market Prices.

	1965	1970	1975	1980	1985	1965-80 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
Non-Agriculture	13,631 (57)	18,787 (58.2)	26,208 (59.7)	37,306 (61.6)	53,314 (63.6)	7.0

(Figures in brackets are per cent of GPP)

Sources: Based on [28 and 20].

Two alternative assumptions are made about the future growth of labour productivity in the non-agricultural 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 non-agricultural sectorⁱⁿ the past. The projection of output growth in the non-agricultural sector (Table C-I) is used along with 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 non-agricultural labour force.

In any period the difference between the projected labour force and non-agricultural employment is the residual labour force remaining on the farm. It should be pointed out that the nature of our projections is such that non-agricultural "employment" also include unemployed labourers in the non-agricultural sector. . The proportion of unemployed in the total non-agricultural labour force is assumed to remain unchanged over the period we are concerned with.

Table C-2

Projections of Total, Non-Agricultural and Agricultural
Labour Force in West Pakistan 1965-85
(Age 10 and above ; in 000's)

	<u>1965</u>	<u>1970</u>	<u>1975</u>	<u>1980</u>	<u>1985</u>
Total	15,904	18,509	21,698	25,291	29,183
Non-Agricultural:					
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. 394]. The estimate of non-agricultural 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 non-agricultural sector of Pakistan as a whole. 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 non-agricultural labour force was in East Pakistan.

Appendix D

Costs of Resettlement of displaced farm labour
in the Non-agricultural Sector

If a farm labourer displaced by mechanization has to be resettled in the non-agricultural 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 exemplified 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 Rs. 3 to Rs. 4 per square yard and this is the rate at which the plots (averaging about 100 square yards) are given on 99 years leases. 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 1959-63 probably represent the opposite extreme from the "plot townships". Here the KDA 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 Rs. 5,000 as shown in Table D-1.

Table D-1
Residential Costs
(Rupees Per Family at 1969 Prices)

	<u>Total Cost.</u>
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	<u>200</u>
	6650
	<u>490</u>
Less Land	6160
Less 20% for labour	<u>1210</u>
Net Social Cost	4950

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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 non-agricultural 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 Rs. 4,000 to Rs. 250,000 per worker. The mean - obtained by

weighting the capital labour ratio for each industry by its average daily employment - is Rs. 16,350 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 Rs. 16,000) 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 Rs. 9,102 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 Rs. 12,000 at the prices of the late 1960's.

Other sub-sectors, 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 Rs. 1,000 to Rs. 4,000 from one district to another, and the simple average of 24 districts comes to Rs. 2,227 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 Rs. 3750 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 Rs. 5,000.

The data about distribution of non-agricultural labour force in these sub-sectors are not available. However, from the relative magnitudes of total value added and rough guesses about per worker value added in these sub-sectors, we assume that in the late 1960's the percentages of total non-agricultural 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 non-agricultural sector as a whole comes out to be Rs. 5,340. Thus the residential cost, K_r , plus the employment cost, K_e , per labourer in the non-agricultural sector is over Rs. 10,000.

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