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Farm Tractorization, Fertilizer Use and Productivity of Mexican Wheat in Pakistan

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Using survey data the impact of tractorization on wheat productivity is examined in this paper. A comparative analysis of yield data indicates that wheat yields on tractor farms are significantly higher than those on bullock farms. It is also found that tractor farms use higher amounts of chemical fertilizers on their wheat crop. The results of production function analysis also confirm the significant contribution of tractorization in achieving higher wheat yields.

I. INTRODUCTION

In addition to the large scale adoption of high yielding varieties of wheat and rice, which are responsive to fertilizer use and the spread of tubewells, the increasing use of tractors has been one of the important developments in Pakistan's agriculture. So far the increasing demand for tractors has been met through imports, which have been stepped up recently. It has been proposed that 15,000 tractors will be imported annually during the Fifth Plan period to satisfy the excess demand for tractors. As a result the stock of tractors in Pakistan is expected to go up from about 71,000 in 1977-78 to about 111,000 in 1982-83 [18].

The increasing use of tractors in the agricultural sector has generated heated debate about their net social benefits for the economy. Those in favour have argued that tractors by increasing draft power supply at the farm level, help in reducing culturable waste land. A greater use of tractors expands cultivated area, permits multiple cropping and reduces the demand for bullocks. It helps release land now used in fodder cultivation for growing valuable food and cash crops. Tractors are also helpful in increasing farm output and farm yield through better tillage, deeper cultivation and timeliness of farm operations [5, 6 and 13].

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However, there are others who do not share this optimism about the yield impact of tractors. For instance, Ahmed in his case study on mechanization in the Punjab[2] did not find any consistent pattern in the crop yields of tractor and bullock farms. He also did not observe any significant difference in the use of modern farm imputs, such as fertilizers and other improved practices between mechanized and bullock farms. This led him to conclude that tractors so far had not served the cause of modernization. A World Bank study [7] has noted: "Certainly the advent of tractors by replacing bullocks can release land from fodder for cash crop production and through reclamation can expand the cultivable area available for cropping but beyond that output increasing possibilities of the tractors involve much more conjecture. And there are others who have argued in this vein and also objected to the use of tractors because of their adverse effects on employment [3]. A similar controversy about the desirability of farm tractorization has been reported for Indian agriculture [3, 22].

It should therefore be clear that output increasing and productivity improving effects of tractors remain a controversial issue in the debate on farm mechanization. The main objective of the present study is to investigate the impact of the use of tractors in place of bullocks on farm productivity. The analysis is confined to wheat crop only. The reason for selecting wheat crop for the analysis is that it is the single most important crop in Pakistan's agriculture and more than 33 percent of the total cultivated area is devoted to its production annually. We have used farm survey data to examine the productivity of Mexican wheat and other related aspects of tractor and bullock farms in Pakistan.[1]

The paper is divided into four sections. Results of the empirical analysis are reported in section II. Some policy implications of the results are discussed in section III, while section IV concludes the discussion. The problems of data collection and sampling procedures are described in Appendix A, and the methodological issues relating to cost-of-production estimates are discussed in Appendix B.

II. RESULTS OF EMPIRICAL ANALYSIS

(A) Tractorization, Farm Productivity and Fertilizer Use

Total agricultural output can be increased with greater employment of land and labour inputs without increasing productivity. Such an expansion in output would reflect the use of existing technology which may, at best, be achieved at constant cost. However, agricultural development, to be viable should contribute to an increase in the productivity of resources employed in the agricultural sector. All

[1] The data used in this study pertain to the production year 1972-73 and were collected through a field survey which was designed to evaluate the effects of the World Bank's Programme for agricultural credit in Pakistan. For details of the field survey, see Appendix A.

the more so because arable land has to face not only increasing population pressure but also growing competition from non-agricultural uses as well. It is, therefore, imperative that productivity of resources already committed to agriculture, especially to farm land, must increase to meet the increasing requirements of food and other agricultural products. This can be achieved by combining more productive factors with the traditional inputs of land and labour and by increasing the efficiency of resource use or through a combination of these approaches.

Following the introduction of high-yielding wheat varieties power constraint has become critical in wheat cultivation, especially in regions where irrigation is widespread. The introduction of mechanical cultivation in Pakistan, as noted above, has been supported by the argument that the removal of the power constraint at the opportune time will not only help in expanding the cropped area but will also allow the sowing of various crops at the proper time, conserve soil moisture and improve the quality of seed-bed preparation. However, the timeliness in the sowing of the seed and the improved quality of cultivation, desirable as they are, are not ends in themselves but only the means for achieving higher productivity reflected through higher crop-yields.

A comparison of farm productivity among the tractor- and bullock-farms should throw light on the impact of tractorization on agricultural productivity. It may also be of interest to analyse the use of chemical fertilizers among the sample farms to estimate the systematic relationship, if any, between tractors and the use of chemical fertilizers. The data on wheat yield and fertilizer use per acre for bullock- and tractor-farms are presented in Tables 1 and 2. These data have been used to test the significance of the differences in yield and fertilizer use between tractor and bullock farms. To neutralize the scale effect, we have also analysed the productivity and the proportion of wheat-crop acreage on sample farms according to farm size. However, as the sample farms were quite large, we had to specify relatively higher ceilings for farm-size categories. Accordingly, for this study, farms have been grouped into two categories: (a) those up to 50 acres and (b) those larger than 50 acres. It should be pointed out here that such an analysis is only suggestive of the effects of tractorization on farm productivity and fertilizer use. In order to assess the exact role of tractors on output and fertilizer use we will have to hold constant other variables influencing fertilizer use and output, such as farm size, labour, etc. The results of such an exercise involving regression analysis are reported below.

A comparative analysis of the yield data, on different farms, reported in Table 1, shows that wheat yield on tractor farms is substantially and significantly higher than that on bullock farms. The analysis of wheat productivity,[2] according to

[2] The productivity analysis is confined to wheat grains only. We ignore wheat *bhusa* (i.e. chaff), which is a valuable by-product of wheat cultivation, for want of relevant data. However, as its output varies proportionately with the production of grains and its exclusion, which was true for the bullock as well as tractor farms, should not affect the overall comparative picture.

Table 1

Proportion of Crop Area in Mexi-Pak Wheat and Per Acre Yields on Tractor and Bullock Farms: 1972-73

Farm Categories	Tractor Farms			Bullock Farms			Percentage Yield Excess of Col. 4 over Col. 7
	Number of Observations	Wheat Area as a % of Total Cropped Area	Yield Per Acre (Maunds)	Number of Observations	Wheat Area as a % of Total Cropped Area	Yield Per Acre (Maunds)	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
All Farms	145	36.0	24.40	34	33.2	21.29	14.61*
Farms Up to 50 Acres	36	33.3	26.99	12	32.6	20.98	28.64*
Farms Greater than 50 Acres	109	36.9	23.85	22	33.4	21.47	11.09**

Note : A maund is equal to 82.3 pounds or 37.3 kilograms.
*Yields on tractor farms significantly higher than those on bullock farms at the 95-percent significance level.
**Yields on tractor farms significantly higher than those on bullock farms at the 90-percent significance level.

the area operated, did not indicate much influence of farm size on output per acre among the sample farms. Wheat yields were significantly higher on tractor farms of all sizes.

The data on fertilizer use indicate that, even though the use of fertilizers on Mexican wheat is quite widespread among the sample farms (Table 2), the use of fertilizer has been much higher on tractor farms than on bullock farms. Further analysis of fertilizer use data indicated the dominance of nitrogenous fertilizers. Only a small proportion of farmers were using phosphate fertilizers. The dominance of nitrogenous fertilizers in the chemical fertilizers used, however, appears more pronounced on bullock farms than on tractor farms, which showed a relatively more balanced use of fertilizers. The amount of nutrients (nitrogen + phosphate) used per acre of wheat on tractor farms was greater by about 22 percent. These differences in the use of chemical fertilizers are also statistically significant.

Table 2

Incidence and Level of Fertilizer Use Per Acre of Mexi-Pak Wheat on Tractor and Bullock-Farms: 1972-73

	Fertilizer Users		Amount of Nutrient (N + P) Used Per Acre (lbs.)
	Number	Percentage	
Tractor Farms*	139	96	103.4
Bullock Farms	30	88	84.4
Percentage Excess of Nutrient used on Tractor Farms over that used on Bullock Farms	—	—	22.1

Note: Users of Phosphate in addition to nitrogenous fertilizers were 55 percent of tractor farmers as compared to only 32 percent of the bullock farmers. (N = Nitrogen, P = Phosphate).

*The use of fertilizer nutrients is significantly higher on tractor farms than on bullock farms at the 95-percent significance level.

(B) Agricultural Credit and Fertilizer Use

Whether the higher use of fertilizers on tractor farms was "due to" tractors, or their better liquidity position or their better access to institutional credit for fertilizer use is difficult to test statistically. Although the average size of tractor

farms was relatively greater, yet even the bullock farms covered by the survey were large by Pakistani standards and thus were unlikely to face serious financial constraints.[3] Similarly, the higher use of fertilizers on tractor farms cannot possibly be explained by their better access to institutional credit on account of their large size. But more important is the fact that during 1972-73, the year to which the data for this study belong, the availability of institutional credit, specifically for fertilizer use, was quite small as compared to the actual amounts involved.

The Agricultural Development Bank of Pakistan (ADBP), the principal source of institutional credit for agriculture, during 1972-73 disbursed loans worth Rs. 41.459 million for fertilizer use in the country. This amount was about 15 percent of the total loans provided by the ADBP in that year [16]. Commercial banks provided about 85.2 million rupees [12] and the co-operative credit societies provided about 32.74 million rupees as loans for all agricultural activities [17]. A full break-down of commercial banks' and co-operative credit societies' agricultural loans by activities is not available. However, if the commercial banks' distribution of loans for agricultural operations was similar to that of the ADBP, the share of fertilizers in their agricultural credit comes to about 12.78 million rupees. The co-operative credit societies' loans are relatively of a short-term nature. Even if 50 percent of their loans were meant for fertilizer use, the total share of fertilizers in their loans amounts to Rs. 16.37 million. Thus the total amount of institutional credit meant for fertilizer use during 1972-73 is estimated at about 70.609 million rupees. During the same period, it is estimated that the total amount spent on the use of nitrogenous and phosphate fertilizers was about Rs. 704.953 million.[4] Thus the amount of institutional credit for fertilizer use in 1972-73 was only about 10 percent and the remaining 90 percent was financed by the farmers from their own savings or from informal sources of credit such as friends, relatives, etc.

The foregoing analysis shows that as the institutional credit for fertilizer use was quite limited as compared to the overall amounts involved, it could not have been a major factor explaining the differentials in the use of fertilizer on the sample farms.

(C) Tractor-Tubewell Combination, Wheat Productivity and Fertilizer Use

It may be argued that both the higher yields and a more intensive use of fertilizer on tractor farms were due to omitted variables, particularly the tubewells.

[3] Average area operated by bullock farms was about 76 acres and that by tractor farms was 115 acres.

[4] Total expenditure on nitrogenous and phosphate fertilizers used. This was estimated by the author from the data on fertilizer use during 1972-73 and the prices paid by the farmers for these materials.

About two-thirds of the sample farms, equally divided between tractor- and bullock-farms, had tubewells. In the following paragraphs, we discuss the influence of tubewells to highlight the irrelevance of the omitted variables for our estimates.

The role of tubewells in the agricultural development of Pakistan is well known and well documented [4, 9, 11]. In order to isolate their impact on farm productivity and use of chemical fertilizers among the sample farms, we analysed the data on wheat yield and fertilizer use by grouping both groups of sample farms according to the presence or absence of tubewells. The results of this analysis are reported in Table 3.

Table 3

Fertilizer Use and Wheat Productivity According to the Presence or Absence of Tubewells on Sample Farms: 1972-1973

	Farms with Tubewells		Farms without Tubewells	
	Tractor Farms	Bullock Farms	Tractor Farms	Bullock Farms
Fertilizer Use Per Acre (Nutrient Pounds of Nitrogen)	77.10*	66.10	78.50	78.10
Yield Per Acre (Maunds)	24.32*	20.66	24.60*	22.61

*Yields and fertilizer use on tractor farms significantly higher than those on bullock farms in the same category at the 95-percent significant level.

A comparative analysis of data on fertilizer use, according to the presence or absence of tubewells within each group of sample farms, does not show any significant difference between the tubewell and non-tubewell farms. In fact the non-tubewell farms had a somewhat higher fertilizer use. Wheat yields within each group of sample farms appear to be insensitive to the presence or absence of tubewells. However, differences in both fertilizer use and wheat yields between tractor and bullock-farms, which own tubewells and which do not, were highly significant. The insignificant role of tubewells on the sample farms may have been due to the fact that all the farms were located in irrigated areas. Moreover, the benefit of tubewell technology is not confined to tubewell farms alone and non-tubewell farms in the tubewell areas also benefit from this technology through purchase of additional water.

(D) Results of Regression Analysis of Fertilizer-Use Data

The results of regression analysis, which features per acre fertilizer use as the dependent variable, are reported below. Farm size and respondents education are treated as independent variables, while tractor is included as a dummy variable.

ln (Nutrient pounds of fertilizer used per wheat acre) =

3.6775 − 0.01884 ln (Area operated) + 0.1957 ln (years of schooling)
(0.21264) (2.20214)

+ 0.450 Tractor Dummy
(1.9896)

$R^2 = 0.0578$, $F = 3.5162$

(Values given in parentheses are t-values.)

The results of the regression analysis bring out the significant influence of tractors on higher fertilizer use. Interestingly enough, the role of education in inducing a higher fertilizer use turns out to be significant as well. However, farm size does not appear to have much influence on per acre fertilizer use. (For review of evidence on the role of farm size and other such factors in fertilizer use in Pakistan, see [10] and [19]). The overall function, although it did not explain much of the inter-farm variation in fertilizer use is significant nevertheless. It should be clear from the foregoing analysis that tractors have played an important role in encouraging a widespread and relatively high fertilizer use.

(E) Results of Production Function Analysis

The higher wheat productivity observed on tractor farms, apart from other factors, may well have been the result of the higher fertilizer use on these farms. What are the contribution and role of tractors in higher productivity? The analysis presented so far does not provide an answer to this question, to answer which we turn to production function analysis.

In order to further test the relationship between higher wheat productivity and tractors we have estimated a few log-linear regression equations, using wheat output per acre as the dependent variable.[5] Explanatory variables included in the equations are farm size, labour use and fertilizer expenses or actual use of fertilizer. These variables are defined on the basis of per wheat acre, while tractor appears as a dummy variable in these equations. Since all the sample farms are irrigated and tubewell irrigation is equally widespread among the sample bullock- and tractor-farms, irrigation has not been included as an explanatory variable in the estimated functions. Moreover, there is not much inter-farm variation in the frequency of

[5] The reason for estimating log-linear relationship is that it gives better fit to the data. The use of log-linear relationship in agricultural production studies is quite frequent and justified on economic grounds [23].

irrigation in the case of wheat crop. Tubewell as a dummy variable was dropped from the regression equation because it did not improve the results. Farms size was included to test the relationship between farm size and productivity.

The reason why we have preferred per acre production function over the conventional production function here is that we had crop-wise data on the use of fertilizer and the casually hired labour. Data on the use of other inputs, such as permanent hired and family labour, tractor time, bullocks, etc., were available at the farm level. Under a system of multi-crop farming, as practised in Pakistan, we can apportion the use of farm-level inputs to different crops on the basis of their area. However, in estimating production function, the use of total crop produce as the dependent variable, and of cropped area and other inputs, estimated indirectly from the farm-level data on the basis of crop acreage, as independent variables introduces problem of multicollinearity. Our objective is to analyse inter-farm yield differentials. This can be done by estimating multicollinearity-free production function in terms of yield per acre. This specification assumes constant returns to scale, which may not be unrealistic to assume in wheat farming in Pakistan.

Elasticity of substitution between capital and labour, though important, is nevertheless difficult to estimate. This is especially so in situations like the one encountered in the present study, where estimating equations involve more than two variables. Also the interpretation of the resulting substitution coefficient is not clear-cut. The function form used in this analysis assumes constant elasticity of substitution.

The results of production function analysis are presented in Table 4. All the coefficients of the estimated equations have positive signs and only farm-size coefficient is not statistically significant. The estimated functions explain about 20 percent of the inter-farm variation in wheat yield on the sample farms. The explained variation, however, appears relatively small but it is not uncommon to find a low value of R^2 in cross-sectional studies. This is because we do not have any control on numerous agronomic and technical factors such as sowing time, method of sowing, the timing of the application of fertilizer and irrigation, crop rotations, planting densities, intercultural practices, etc.

The results of regression analysis do not indicate any significant relationship between farm size and productivity among sample farms. The coefficients of fertilizer expenditure and labour use are highly significant. As the functional forms used are log-linear, the coefficients of the respective variables are output elasticities of the factor inputs. The respective coefficients indicate the percentage change in wheat output per acre in response to a one-percent change in the given inputs, other things remaining the same. The coefficient of tractor, used as a dummy variable, was positive and statistically significant. This indicates positive contribution of tractors in increasing wheat productivity. From the results it appears that, other things being equal, wheat output per acre was higher on tractor farms than on bullock farms by about 12.5 percent.

Table 4

Estimated Coefficients of Production Function (Mexi-Pak Wheat): 1972-73
(All Variables are in Natural Logarithms Except the Dummy Variables)

Constant	X_1	X_2	X_3	X_4	X_5	X_6	Number of Observations	R^2	F-Ratio
2.0860	0.02075 (0.73399)	0.13974 (5.44371)	0.09737 (2.50308)	–	–	0.12531 (1.74543)	179	0.19681	10.4754
2.13057	0.01992 (0.7009)	–	0.09423 (2.41566)	0.11234 (4.22967)	0.11496 (1.99687)	0.11767 (1.62125)	179	0.19616	8.2442

Note: X_1 = Farm Size (Acres).
X_2 = Fertilizer Expenditure Per Wheat Acre (Rs.).
X_3 = Labour Use Per Wheat Acre (Mandays).
X_4 = Nutrient Lbs. of Nitrogen Used Per Wheat Acre.
X_5 = Use of Phosphate Fertilizer as Dummy Variable. 1 For Users, 0 For Non Users.
X_6 = Tractor Used as Dummy Variable. 1 For Tractor Farms, 0 For Bullock Farms.

(The values reported in parentheses are t-values.)

To see the importance of the use of phosphate fertilizer in wheat productivity, we split fertilizer use by nutrients and treat nutrient pounds of nitrogen as an independent variable. The use of phosphate fertilizer was included as a dummy variable, because there were many non-users of this fertilizer. Other variables like farm size, labour use, etc., are as defined previously. The results of this analysis indicate that, other things being equal, wheat productivity on farms using phosphatic fertilizers was 11.5 percent higher than on non-user farms. Similarly, the coefficient for tractor dummy was also significant indicating higher per acre wheat output on tractor farms. Two important factors in higher wheat productivity on tractor farms appear to be (i) the use of phosphate fartilizer and (ii) the use of tractors. It may be recalled that the incidence of the use of phosphate fertilizer has been much higher on tractor farms than on bullock farms.

As the sample farms were spread out in the irrigated regions of Pakistan there is not much likelihood of any systematic bias arising from land quality or climate in favour of the tractor farms. Given the well-known inverse relationship between farm size and productivity under subsistence farming, it is interesting to observe higher productivity on tractor farms in spite of the fact that the average farm size in case of tractor farms was relatively large. Here we did not find any significant relationship between farm size and productivity. From the results one could infer that tractors, by neutralizing the negative impact of larger farm size on productivity in the traditional set-up, have made a positive contribution to farm productivity.

(F) Tractorization and Average Variable Cost Per Maund of Wheat

The foregoing analysis has shown that higher wheat yields and higher use of fertilizer nutrients are associated with tractor farms. This indicates that the substitution of tractor for traditional sources of draft power and their role in encouraging more widespread and higher use of fertilizer have been helpful in increasing farm productivity.

To compare the overall efficiency of tractor- and bullock-farms in wheat production and also to cross-check our previous findings of higher productivity on tractor farms, we have analysed the average variable cost of production per unit of wheat. The methodology and variables used in these calculations are discussed in Appendix B.

The results of the cost-of-production estimates, presented in Table 5, show that in spite of the higher per acre production costs incurred on tractor farms, the average variable cost of producing one maund of wheat was lower on these farms. This was because of significantly higher yields obtaining on tractor farms. On bullock farms, the average variable cost of producing one maund of wheat was about 7.8 percent higher than on tractor farms. The lower unit production cost of wheat also supports our conclusion about the positive contribution of tractors in higher wheat productivity.

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	(0.73399)	(5.44371)	(2.50308)			(1.74543)			
2.13057	0.01992	–	0.09423	0.11234	0.11496	0.11767	179	0.19616	8.2442
	(0.7009)		(2.41566)	(4.22967)	(1.99687)	(1.62125)			

Note: X_1 = Farm Size (Acres).
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Table 5

Total Variable Costs Per Acre of Wheat and Average Variable Cost of Producing one Maund of Wheat on Tractor and Bullock Farms: 1972-73

	Tractor Farms			Bullock Farms		
	All Farms	Farms Up to 50 Acres	Farms Greater than 50 Acres	All Farms	Farms Up to 50 Acres	Farms Greater than 50 Acres
1. No. of Observations	145	36	109	34	12	22
2. Total Variable Costs (Rs.)	354.15	397.69	349.04	333.34	353.51	323.75
3. Yield (Maunds)	24.40	26.99	23.85	21.29	20.98	21.47
4. Average Variable Cost Per Maund of Wheat (Rs.)	14.51	14.73	14.63	15.65	16.85	15.08

	All Farms	Farms Up to 50 Acres	Farms Greater than 50 Acres
Percentage Excess of Average variable Cost per Maund of Wheat on Bullock Farms over that on Tractor Farms	7.86	14.39	3.06

Source: [Appendix C].

(G) Tractorization and Employment

The impact of tractorization on employment has been at the heart of the controversy over farm mechanization. It may be interesting to know as to what light our study throws on this aspect of the problem. The overall use of labour per acre of wheat was somewhat higher on bullock farms than on tractor farms.[6] This may be guessed from the overall higher expenses for labour use reported in Appendix C. However, the role of hired labour, both casual and permanent, in farming appears to be greater on tractor farms than on bullock farms. The present study does not lend strong support to the proposition that mechanization in the rural sector necessarily has an adverse effect on employment.

Estimates of total changes in labour use at the national level in the wake of farm mechanization, though highly desirable, are difficult to work out in the absence of detailed information about mechanization and labour used in the pre- and post-mechanization periods. The Agricultural Machinery Census conducted in 1975 [14] provides information on the number of households reporting a decrease (increase) in the labour used on their farms. The census data do not indicate the extent of increase or decrease in the overall labour use. Nevertheless, the proportion of households reporting an increase in their use of labour, induced by tractor, on all the farm size categories, was higher than the proportion of households reporting a decline in their labour use. The conclusion is in accord with that reached by Ahmed [1]. He has observed that in the tubewell areas, all forms of mechanization, i.e. only tractors or tractor combined with thresher, bullocks with tractor or bullocks with thresher, lead to an increase in employment when compared to traditional forms of cultivation. He argues that with no water constraints, mechanical power, through its effects on cropping pattern and intensity, tends to create more jobs than it displaces.

A study on displaced tenants [21] indicated that, as a consequence of mechanization by the landlords, a great majority of tenants after their displacement, continued to remain in the farming business. However, this continuation in farming necessitated different types of locational, occupational and farm-size adjustments. The displacement led to a reduction in farm size. Furthermore, reduction in size was more severe for owner-cum-tenants and relatively large tenants. The ejectment also forced many a tenant to migrate from his previous village to another village.

III. POLICY IMPLICATIONS

During the early Seventies — the period when data for this study were collected —, there was less than one tractor for 1000 acres of farm area in Pakistan [15]. Also, even such farmers as possessed tractors then probably did not yet have much experience in tractor cultivation. Under these circumstances, the positive impact of tractors on farm productivity appears to be noteworthy.

[6] It includes casually hired, permanent hired and family labour.

The data used in this study, collected by the Agricultural Development Bank of Pakistan (ADBP), belong to large farms. The results of the study, therefore, may not be strictly applicable to small farms. The ADBP, by providing loans for tractors, tubewells, etc., has championed the cause of farm mechanization in Pakistan. As such, it is plausible that the data collected by them might have had some bias in favour of tractor farms. However, it needs to be pointed out that neutral observers, who checked the quality of the data, found it satisfactory. However, the possibility of some bias, which is true for any survey data, cannot be altogether ruled out.

The results of this study clearly point to the superiority of tractors over bullocks as a vehicle of agricultural growth. However, under the prevailing structure of farm holdings, the types of tractors currently in use are beyond the reach of a great majority of the farmers. It is estimated that about 68 percent of the total farms, in the country, commanding 34 percent of the cultivated area, are below 12.5 acres [20]. However, for effective agricultural development these farms must also benefit from modern inputs and technology. Small tractors which have been effectively used elsewhere on small holdings may provide the answer to the problems of adequately increasing the draft-power supply on small farms. However, this requires that small farmers have easy access to institutional credit.

The use of tractors alone may not be sufficient for realizing the objectives of agricultural development, as there exists substantial potential for increasing farm productivity even on the tractor farms. This is reflected in the yawning gap that exists between the maximum yields obtained on some of the tractor farms and the average yields prevailing on the majority of the sample tractor farms.[7] This big gap between the average and maximum yields is, perhaps, due to the unbalanced fertilizer use, not based on any scientific soil tests, lack of other complementary inputs and practices, poor technical know-how about improved technology, etc. Existing institutional and technological constraints hampering agricultural development must be examined and analysed through appropriate micro studies and measures adopted to bridge this gap.

The modern factor inputs are highly energy-intensive, whose prices in recent years have shown a marked upward trend. This trend is likely to persist in the future. At the same time, the use of such inputs is critical in agricultural development and is likely to become even more critical in the future. This will result in increased production costs, which must be counter-acted by increasing the efficiency of their use. The increased use of modern inputs will tax management capacity and capability of the farmers, and necessitates an improvement in farmers' technical knowledge about farming methods and modern inputs. This will have to be supported by a strengthening of agricultural research institutions, market intelligence and extension services so that they can effectively respond to the emerging situations.

[7]The maximum yield obtained on tractor farms was 45 maunds of wheat while the average yield was only 24.4 maunds.

IV. CONCLUSIONS

Using data from a field survey, we have analysed productivity behaviour, adoption of fertilizer technology and intensity of its use, and average variable cost per unit of output in the cultivation of Mexican wheat under two broad technological set-ups, viz. tractor farming and bullock farming. The results of the analysis, discussed at length in the previous sections, have indicated that as a general rule higher productivity obtains on tractor farms than on bullock farms. A part of the gains in productivity may be attributed to a more balanced and higher use of fertilizers induced by tractorization. The impact of farm size and tubewell irrigation on wheat productivity and fertilizer use among the sample farms was also analysed. interestingly enough, the influence of these factors, either on fertilizer use or on productivity, turned out to be insignificant. The present study also pointed to the employment-generating potential of tractorization: the use of hired labour on sample tractor farms tended to be relatively higher.

Production function analysis also supported the findings that wheat productivity tends to be higher on tractor farms. Other things remaining the same, wheat productivity on tractor farms, due to tractorization, was about 12.5 percent higher than on bullock farms. Also, farms using phosphate fertilizers showed significantly higher wheat yield.

The overall efficiency in wheat production, reflected in lower unit cost of wheat output, also appears to be greater on tractor farms than on bullock farms. From these results it seems that tractorization has facilitated agricultural development by increasing farm productivity, partly through an induced increase in the use of fertilizers on tractor farms.

Numerous changes in the rural sector have taken place since the undertaking of this survey in 1974. The construction boom in the Middle East has encouraged large-scale outmigration of both skilled and unskilled labour from Pakistan. Tenurial arrangements and labour markets in the rural areas have witnessed profound changes. The prices of almost all the farm inputs and outputs have substantially increased. The use of tractors is no more confined to owner farms. Besides tractorization, other forms of mechanization, especially the use of threshers, are also increasing rapidly. Farmers who do not own these machines are renting their services from those who have them. All these changes call for undertaking a comprehensive field survey, which should include all farm sizes and tenurial groups, to throw light on the effects of these changes in the rural economy and verify the results of this study.

Appendix A

DATA AND SAMPLING PROCEDURE

The data for this study pertain to the production year 1972-73 and were collected through a field survey which was designed to evaluate the impact of the World Bank's programme for agricultural credit in Pakistan. The programme administered by the Agricultural Development Bank of Pakistan (ADBP) was primarily concerned with loans for mechanization and tubewell installation. The survey was organized by the Agricultural Development Bank of Pakistan in February, March and April of 1974. Staff members of the ADBP, having graduate training in agriculture, interviewed the sample farmers, who were selected through the following procedure:[1]

(1) Seventy farmers were randomly selected from those who were interviewed in the 1970 ADBP survey of tractor loanees.[2] This group of farm was referred to as the "resurvey farms".

(2) Ninety farmers were randomly selected from those who received an ADBP tractor loan in 1969 and were referred to as the "new loanees".

(3) Forty farmers who did not own a tractor and were not loanees of the ADBP constituted the control group. To be effective, the control group had to be comparable with the sample of tractor farmers in terms of average farm size. As no listing of the population of bullock farmers was available, the interviewers were advised to select bullock farmers in the following manner:

"(a)When you have visited the first two of your new loanee farms, attempt to find a bullock farms equivalent in size to the largest of the two farms just visited. (b) When you have visited another two new loanees farms attempt to find a bullock farm equivalent in size to the smallest of the two farms just visited. (c) Continued in this way alternatively looking for bullock farms equivalent to the largest, then to the smallest, of each pair of new loanee farms visited" [8].

The interviewers were advised that while looking for bullock farms they enquire from the owners of tractor farms or from other villagers about the 'desired' size of a bullock farm in the absence of a tractor.

The survey yielded 196 completed questionnaires, of which 160 were for tractor farms and 36 for bullock farms. However, the present study is based on 145

[1] This draws heavily on McInerny and Afzal Hussain's Notes on the Survey Schedule and its Completion [8].

[2] During the 1970 survey 220 tractor farmers were randomly selected out of those farmers who were granted loans by the ADBP in 1967.

tractor farms and 34 bullock farms as some of the farmers had not grown Mexican wheat and a few questionnaires could not be traced. The break-down of these farms according to the area operated is given below:

	Tractor Farms		Bullock Farms	
	Number	Per-centage	Number	Per-centage
Farms up to 50 acres	36	25	12	35
Farms greater than 50 acres	109	75	22	65
Total	145	100	34	100

An overwhelming majority of farms operating more than 50 acres fell in the range of 50 to 150 acres.

The survey was designed to evaluate the effectiveness of the World Bank's agricultural development loans in Pakistan provided through the Agricultural Development Bank of Pakistan (ADBP). During the initial stages of the ADBP's loaning, the principal beneficiaries of the programme were relatively large farmers. Therefore, the respondents of the survey were naturally large farmers. The control group, i.e. bullock farmers, in order to be comparable with the tractor farmers, thus, had also to be from the large farmers. Hence the results of the study, strictly speaking, may not hold for small farms.

The survey conducted by the staff of the ADBP, the agency concerned with providing loans for tractors etc., might have had some bias in favour of tractor farms. However, senior officers of the ADBP supervised the survey and also provided training to the interviewers in conducting farm-management surveys, emphasizing the importance of neutral observations. Outside observers engaged to check quality of the data did not find any systematic bias in the survey data. Nevertheless, the possibility of some bias cannot be ruled out. But this is true for any survey.

Appendix B

METHODOLOGY FOR ESTIMATING VARIABLE COSTS

The cost of production estimates, as discussed in the text, include expenditure on chemical fertilizers, seed, canal water, land revenue, the actual wages paid to the casually hired labour for wheat, the opportunity cost of family and permanent hired labour and bullock labour available per crop acre. In the case of tractor farms, the opportunity cost of tractor time used per crop acre was also added to the cost of production. These estimates, however, do not include land rent for want of data. The inclusion of land rent, which is largely influenced by the location of farms rather than by the intrinsic fertility of the land, would not have altered the comparative picture unless the tractor farms were concentrated around urban centres and commanded substantially higher rentals. The sample farms were widely spread out in the irrigated areas of Pakistan and followed a mixed cropping pattern; wheat, cotton, rice, sugarcane, maize and fodder were the principal crops commanding around 90% of the crop area. Depreciation allowance for fixed farm assets and interest on working capital have not been included in the cost estimates, either. As our main interest in working out these estimates was to cross-check our previous findings, we believe that the inclusion of these data would not have altered the overall comparative picture.

Data on the actual use/expenditure on chemical fertilizers, use of casually hired labour and expenditure thereof, and seed rate for wheat crop were directly available from the field survey and posed no problem. Canal water charges for various crops and land revenue are fixed by the government and were taken from Ahmed's study [2]. However, we had to work out the use of family and permanent hired labour, tractor hours used and the estimate of their cost indirectly from the farm-level information. A few points on this estimation are in order.

Farming in Pakistan is a multi-crop enterprise and farmers seldom maintain records about the actual use of farm labour and farm machinery for specific crops. To overcome this problem, following Ahmed [2], we have assumed 288 working days for manual labour. By multiplying the total farm workers (family workers and permanent hired workers) by 288 and dividing the figure thus obtained by the actual crop area, we estimated the average number of man-days used per crop acre. The maintenance cost of bullock labour per crop acre was derived by multiplying the number of bullocks available per acre by their maintenance cost. As the bullocks have to be maintained throughout the year, we have worked out their opportunity cost, assuming their availability on all the 365 days of the year.

We gleaned the availability of tractor time per crop acre from the actual use of tractor time on the farm by dividing the total tractor hours used on own farm by the cropped area. Luckily, data on these items were available.

The opportunity cost of family labour per acre was worked out by using the wage rate applicable for permanent hired labour. We worked out two estimates of this (i) by using the overall sample wage rate for permanent hired labour, and (ii) by using the category-specific wage rate. The wage rate paid to casually hired labour was not used to work out the opportunity cost of family labour. It may be pointed that most of the casual labour hired for wheat is either at the sowing time or at the harvest time and during these periods labour demand is at its peak and wage rates are accordingly higher.

The wage rates of permanent hired labour used to impute the cost of family labour appear quite realistic. The overall sample wage rate for permanent hired workers was Rs. 3.68 per day while the average wage rate for tractor farms was Rs. 3.87 for all tractor farms, Rs. 3.24 for farms up to 50 acres and 4.08 for farms greater than 50 acres. The wage rates for bullock farms worked out to be Rs. 2.84, 2.91 and 2.79 for all bullock farms, farms up to 50 acres and farms greater than 50 acres, respectively. These calculations assume that alternative employment opportunities for family labour were available. However, if it were not true, the opportunity cost of family labour is overstated and our cost of production estimate would be overstated accordingly. However, as there were really no substantial differences in the per acre use of family labour, the violation of this assumption should not significantly affect the overall picture. The costs for bullock labour and tractor use were arrived at by multiplying their per acre availability by the maintenance cost of bullocks and the rate at which tractor was hired out for custom work. These rates were Rs. 6 for a bullock pair per day and Rs. 14 per tractor hour, respectively. These estimates for the production year 1972-73 were taken from the farm management records of the Agricultural Development Bank of Pakistan.

The results of this exercise are presented in Appendix C.

Appendix C

Total Variable Cost Per Acre of Wheat, Variable Cost Per Maund of Wheat, Gross Income and Net Income Per Acre of Wheat on Tractor and Bullock-Farms : 1972-73

		Tractor Farms			Bullock Farms		
		All Farms	Farms Up to 50 Acres	Farms Greater than 50 Acres	All Farms	Farms Up to 50 Acres	Farms Greater than 50 Acres
1.	Fertilizer Costs (Rs.)	62.1	75.3	57.7	47.3	48.8	46.5
2.	Seed Costs (Rs.)	21.6	21.4	21.7	20.1	19.5	20.5
3.	Canal Water Rates (Rs.)*	10.4	10.4	10.4	10.4	10.4	10.4
4.	Land Revenue (Rs.)*	12.5	12.5	12.5	12.5	12.5	12.5
5.	Casual Labour Wages (Rs.)	45.5	69.4	49.4	42.7	45.2	41.3
6.	Opportunity Cost Per Crop Acre of Family and Permanent Hired Labour (Rs.)						
	(i) Using Overall Sample Wage Rate	73.82	104.18	63.38	92.04	109.77	84.12
	(ii) Using Specific Wage Rate	77.63	91.84	70.38	71.03	86.81	63.78
7.	Maintenance Cost of Bullock Labour (Rs.)	33.82	25.85	36.52	129.31	130.30	128.77
8.	Opportunity Cost of Tractor Use Per Crop Acre (Rs.)	90.6	91.00	90.44	–	–	–
9.	Total Variable Cost (Rs. Per Wheat Acre)						
	(i) Using Overall Sample Wage Rate	350.34	410.03	342.04	354.35	376.47	344.00
	(ii) Using Specific Wage Rate	354.15	397.69	349.04	333.34	353.51	323.75

Continued –

Appendix C – (*Contd.*)

10.	Yield Per Acre (Maunds)	24.40	26.99	23.85	21.30	20.98	21.47
11.	Variable Cost Per Wheat Maund (9 ÷ 10) (Rs.)						
	(i) Using Overall Sample Wage Rate	14.36	15.19	14.34	16.63	17.84	16.03
	(ii) Using Specific Wage Rate	14.50	14.73	14.63	15.65	16.85	15.08
12.	Gross Income Per Wheat Acre (Rs.)**	504.35	557.88	492.98	440.27	433.66	443.79
13.	Net Income Per Wheat Acre (Rs.) (12 ÷ 9)						
	(i) Using Overall Sample Wage Rate	154.01	147.85	150.94	85.92	57.19	99.7
	(ii) Using Specific Wage Rate	150.2	160.19	143.94	106.93	80.15	120.04

*These figures are taken from Ahmed's study [2].

**Gross income per acre = yield X average sale price per maund of wheat. The average sale price for the entire sample was Rs. 20.67 per maund.

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