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Wealth Effects of the Green Revolution in Pakistan

FAIZ MOHAMMAD*

INTRODUCTION

It can hardly be denied that since the late Sixties, the introduction of High-Yielding Varieties (HYVs) of a number of commodities, along with tubewell irrigation and chemical fertilizers, has significantly improved the overall agricultural productivity in Pakistan [12; 15]. However what is still being debated is the effect of this phenomenon, generally termed "Green Revolution", on rural income-distribution in a country where ownership and control of productive resources are far from evenly distributed.[1] Studies by Khan [13] and Chaudhry [7] in particular have generated a great deal of interest in this subject because of their conflicting conclusions. Khan, on the basis of his study of the Punjab and Sind, concludes that the Green Revolution, while generally being beneficial, did not benefit the small farmer as much as it did the large farmer.[2] As a result, it led to a widening of inter-farm and inter-regional income inequalities. According to him, new varieties, which were relatively more profitable, were adopted more widely by large farmers than by the small ones. Similarly, compared with small farmers, large farmers had greater access to, and control of, modern inputs, institutional credit and tractorized farm power, enabling them to gain still more from the new technologies.

Chaudhry, on the other hand, almost totally disagrees with Khan's line of argument [7; 8]. He argues that the Green Revolution in fact significantly improved the relative income positions of small farmers *vis-à-vis* the large ones. According to him, while it may be true to some extent that large farmers were "leaders" in the adoption of modern technologies, small farmers did not lag far behind in catching up with the leaders. Similarly, large farmers might have used relatively more chemical

*The author is Senior Research Economist at the Pakistan Institute of Development Economics, Islamabad.

[1] The term Green Revolution, which initially referred to bio-chemical changes in agriculture, is also extended now to include the use of tubewell irrigation and mechanization in this sector [13]. For the continuing debate on the effects of Green Revolution, see Chaudhry [7].

Here, the term 'large farmers' refers to farmers operating 50 acres or more, whereas 'small farmers' would mean farmers operating less than 12.5 acres. Farmers with farm area between 12.5 acres and 50 acres are termed 'medium farmers'.

fertilizers, but small farmers, using local manures, obtained "a higher and better soil-nutrient balance than is obtained by large farmers". These factors, along with their superior management practices and efficient use of family labour, have allowed small farmers to get higher per acre yield than that obtained by large farmers.

In our view, both of these studies, despite making a very useful contribution to the literature on the subject, were deficient in the light of the following points.

1. They both appear to emphasize relative gains of different farmers and ignore the amount of "absolute gains" (or wealth) made by them. We believe that wealth plays an equally important role in the future course of an individual's income.
2. While Khan may be right in his conclusion that the Green Revolution was not neutral to scale in Pakistan, his analysis did not take care of the points raised by Chaudhry about the small farmer's managerial superiority and his ability to catch up with the large farmer. In fact, both of these studies lack a theoretical framework within which the effect of a new technology on the farmer's income could be studied.
3. As regards Chaudhry's study, it is based on a weak data-set, as pointed out by Khan [13]. However, even if one is to accept his empirical findings, it is not sufficient to conclude that a farmer's income would have continued to improve after that. This is so because "some" additional gains can not necessarily change a farmer's wealth position, without which income distribution would not change very much.

This paper aims at using a theoretical framework to study the nature of gains accruing to different types of farmers from the use of new agricultural technologies. Allowing for the fact that the rate of return from a new technology could go down over time and that not all farmers adopt a technology at the same time, we try to show that those who *lead* in this process accumulate relatively more wealth and could continue to do so as long as they maintain their leadership in the field. We then try to examine the experience of Pakistan in the light of this framework to draw inferences about wealth distribution in the agricultural sector.

The paper is divided into three sections. In Section I, an attempt is made to model the implications of technical innovations where the technology-adoption behaviour differs by farm size. Section II looks at rates of return from different agricultural technologies and patterns of their ownership and use in Pakistan. The paper is concluded in Section III.

I. RETURNS TO TECHNOLOGICAL INNOVATIONS UNDER VARYING TECHNOLOGY-ADOPTION BEHAVIOUR

One of the main objectives of a new technology is to improve productivity and thereby increase the profitability of an economic venture. However, it is

commonly observed in the industrial world that the net return from a new product (innovation) does not increase for ever [32].[3] Barring the very early phase in the life of an innovation, when, due to research and development and promotional costs, it may be low, the net return is usually high in the beginning and declines after some time. This could happen mainly because over time, as a technology becomes commonly available, the number of competitors also increases, leading to a decrease in the quasi-rent earned by the early producers/users. Once the rate of return has fallen below a certain limit (set by the opportunity cost of the capital invested), the product may be totally abandoned. Typically, the dynamic path of return from an innovation can be described by a curve such as A in Fig. 1. In Fig. 1, OX measures the time in the life of an innovation and OY the rate of return from it over time. The line 'mm' indicates minimum return required by a producer to remain in the market, which he may do till time t*. At t_1, although the return is equal to the minimum required, he could continue to increase production beyond this point as he expects higher return in the future.

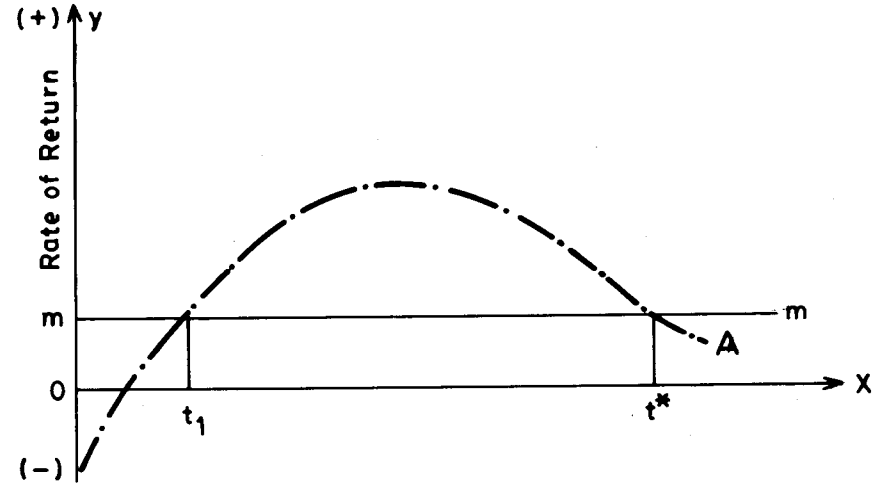

Fig. 1 Dynamic Path of Return from a Technology

[3] Although the 'product cycle' hypothesis refers to the behaviour of new products, this could equally be valid for a new technology. Innovations are nothing but embodied technological improvements.

Now let us suppose that a series of technological changes are taking place one after the other, all having a return-pattern similar to curve A in Fig. 1. Then, assuming also that every new technology is better in terms of its profitability, the dynamic path of returns from those technologies can be depicted by curves such as A, B and C in Fig. 2.

Now, finally let us suppose that there are two types of producers: large and small. The large producer, because of his better financial position or technical knowledge, adopts every technology first and at a time when profit is still quite high. The small producer, on the other hand, being relatively more risk-averse, waits till he is sure of the profitability of an innovation. If the two types of technology-adoption behaviours are repeated over time, it can be easily shown that the benefits drawn by the large producer from innovations would always be higher than those drawn by the small one.

For this, let us look at Fig. 2 again. Suppose the large producer adopts innovation A at time t_1, and at t_2 the small producer also joins him. However, by that time innovation B is also in the field and the large producer, who compared with the small one, not only had more wealth to begin with but also accumulated some more by making use of profitable innovations, is in the best position to invest

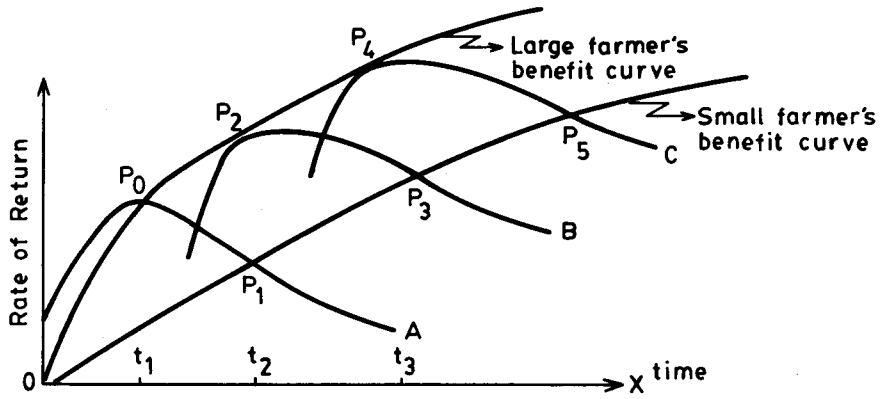

Fig. 2. Dynamic Path of Gains from Changes in Technology of Large and Small Farmers

in this technology. This would mean that for the investment at time t_2, when the small producer's profit rate is P_1, the large producer earns P_2 (higher than P_1) rate of return from a new technology. Repeating similar behaviours of the two types of producers for other innovations would make the 'benefit curve' of the large producer (a combination of P_0, P_2, P_4, etc.) upward-sloping and higher than that of the small producer (a combination of P_1, P_3, P_5, etc.).

The upward-sloping shape of these curves is not, however, necessary. They could be constant or downward-sloping, depending on assumptions about returns from future innovations. But what is important about them is that, as long as the large producer remains a leader in the adoption of new technologies, his benefit could stay higher than that of the small producer.

A few qualifications about these results are warranted here. Firstly, we must assume that no major change is introduced by the government to alter the wealth positions of different producers. Secondly, it is essential that early adopters of a technology should not have to bear the cost of inventing that technology. In other words, R&D and promotional costs are not borne by the early users. Thirdly, small producers are not superior in the use of an old technology to such an extent that their gains outweigh the previous gains of large producers from the existing technology or their current gains from an advanced technology. For example, we rule out the possibility that at time t_2 small producers could be at S_1 whereas the large producer is at P_2. This is not an unrealistic assumption, as, for example, it is highly unlikely for the total benefit (wealth) earned by the small farmer from High-Yielding Varieties (HYVs) alone to be more than that earned by the large farmer from those crops and a tractor taken together.

We do not, however, rule out the possibility of small farmers being more efficient in the use of a technology than the large ones and thus their being able to earn more income per acre over a given period of time. However, at best, what this could do is to shift upward the benefit curve of small farmers and not let the gap between the two curves widen over time. But, in view of the fact that the wealth accumulated by large farmers from one innovation keeps them ahead of others in availing themselves of new profitable opportunities, there is every probability that the gap between the two benefit curves would widen over time. In this way, wealth distribution by farm size would become further unequal.

II. AGRICULTURAL TECHNOLOGIES IN PAKISTAN: RATES OF RETURN AND ADOPTION BEHAVIOUR BY FARM SIZE

Keeping in view the theoretical model described in Section I, we now try to examine rates of return from agricultural technologies and their adoption by size in Pakistan. Before doing so, however, it is important to mention that as far as the research-and-development costs of agricultural technologies are concerned, they have

been generally borne by the government in Pakistan. The government uses its experimentation stations, set up in universities and research centres, to determine the suitability of new seeds before allowing their use. In most cases, it imports seeds of new varieties at its own expense. Price and credit policies are then used to encourage farmers to adopt new seeds [20]. The government credit policy has been particularly instrumental in facilitating the use of fertilizers, tractors and tubewells. In 1972-73, for example, more than 66 percent, and in 1982-83 more than 80 percent of the loans advanced by the Agricultural Development Bank of Pakistan went to those three items [22]. An important feature of such loans was that on both 'per acre' and 'per household' bases large farmers received a much larger amount than that granted to small- and medium-sized farms.[4] This should have further strengthened the large farmer's ability to adopt new technologies.

A. Dynamic Behaviour of Rates of Return from Agricultural Technologies in Pakistan

The profitability of an innovation can be assessed through a number of indicators. A simple and perhaps commonly understood indicator could be 'net revenue as a percentage of total investment'. But to be able to calculate this we should have data on costs and prices of a number of items relating to the technology. Such data are almost impossible to get in Pakistan. Therefore, we have tried some indirect measures to indicate the nature of returns from various technologies over time.

Only three types of technologies have been considered here. They are (i) High-Yielding Varieties of wheat and rice; (ii) Tubewells; and (iii) Tractors.

(i) *Return from High-Yielding Varieties of Wheat and Rice*

Income from High-Yielding Varieties can be estimated by taking into account the yields gained and costs incurred in producing them. Accordingly, we estimated two types of ratios to throw some light on the profitability of new varieties of wheat and rice. They are

$$\text{Yield Ratio } (YR_i) = \frac{\text{Average per acre yield from improved varieties of an } i\text{th crop}}{\text{Average per acre yield from local varieties of an } i\text{th crop}}$$

[4] In 1980, per acre credit available from institutional sources was between Rs 16 and Rs 52 for small farmers and between Rs 73 and Rs 84 for the large ones. Similar amount on per household basis was in the range of Rs 38 to Rs 183 and Rs 4700 to Rs 12041 for the respective categories [25].

$$\text{Cost Ratio } (CR_i) = \frac{\text{Average per acre cost of growing improved varieties of an } i\text{th crop}}{\text{Average per acre cost of growing local varieties of an } i\text{th crop}}$$

where $i = 1, 2$ (namely, wheat and rice)

For the new seed to be more profitable than the local one, the value of YR_i has to be more than unity. The farther away this ratio is from unity, the greater is the chance that the new seed is profitable. Based on secondary data from official sources, estimates for YR_i are obtained for a number of years between 1966-67 and 1982-83,[5] and are presented in Table 1. As regards CR_i, unfortunately, data were available for one year only. Therefore, whereas on the basis of YR_i we could be somewhat more confident about the gross profitability of new seeds, no strong conclusion can be drawn about net returns from them.[6] Nevertheless, from Table 1 the following observations can be made about the nature of return from new varieties.[7]

(i) In the case of wheat, it is very clear that the improved (Mexican) varieties were much more profitable, compared with the local varieties, in the early period (1967 to 1970). However, with the passage of time, the difference in yields of the improved and local varieties went down. For example, in 1966-67 *YR* for wheat was 2.88, which went down to 2.27 in 1972-73 and to 1.78 in 1979-80.

(ii) For rice (IRRI), there is also a negative trend in *YR* but the decline here seems to be somewhat more rapid. For example, in 1966-67 *YR* for rice was 2.93, which remained the same in 1966-67 but dropped drastically in 1968-69 to 1.91 and then to 1.39 in 1970-71. The ratio improved marginally over time, which might indicate a minor increase in the profitability of IRRI varieties.

(iii) If the 1972-73 'cost ratios' are any guide, one could say that net returns from new seeds were also positive. In 1972-73, *CR* for wheat was 1.76 whereas *YR* was 2.27. This means that the increase in costs per unit of

[5] See Table 1 for data sources.

[6] We can have some idea of net return by subtracting CR_i from YR_i.

[7] In this study we have ignored the differences in rates of return among various farm categories as this was not central to the thesis presented here. However, if we consider those differences, then, most probably they would reinforce our results, as, according to Ahmad [1], and Gotsch [10], rates of return from tractors on large farms were higher than those on small or medium farms.

Table 1

Some Indicators of Return from Modern Agricultural Technology in Pakistan for Selected Years

Years	Ratio of per Acre Yields and Costs of Improved Varieties to Local Varieties				Index of Light Diesel Prices	Installation Cost of Tube-well	Index of Installation Cost of Tube-well	Purchase Cost of Tractor plus Accesso-ries	Index of Purchase Cost of Tractor	Tubewell Water Rates Rs Hour	Index of Tubewell Water Rates	Rental Rates of Tractor Rs Hour	Index of Rental Rates of Tractor
	Yield		Cost										
	Wheat	Rice	Wheat	Rice (IRRI)									
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
1965 or earlier	NA	NA	NA	NA	100	8700	100	NA	NA	2.77	100	NA	NA
1966-67	2.88	2.93	NA	NA	103	NA	NA	12035	100	NA	NA	7.78	100
1967-68	2.80	2.93	NA	NA	106	NA	NA	NA	NA	NA	NA	NA	NA
1968-69	2.35	1.91	NA	NA	110	9900	114	NA	NA	NA	NA	NA	NA
1969-70	2.35	1.67	NA	NA	110	9900	NA	19110	159	NA	NA	NA	NA
1970-71	2.51	1.39	NA	NA	110	12000	138	NA	NA	2.98	108	NA	NA
1972-73	2.27	1.42	1.76	1.21	138	NA	NA	NA	NA	NA	NA	NA	NA
1975	2.19	1.39	NA	NA	310	14197	163	39455	328	4.35	157	13.70	176
1977-78	2.02	1.45	NA	NA	314	22197	255	NA	NA	NA	NA	NA	NA

Continued –

Table 1 – (*Continued*)

1979-80	1.78	1.59	NA	NA	607	22197	255	67145	558	10.85	392	26.00	334
1980-81	–	–	NA	NA	924	22197	255	NA	NA	10.29	371	27.50	353
1982-83	1.82	1.68	NA	NA	955	22197	255	NA	NA	NA	NA	NA	NA

Sources: For Columns 2 and 3, [22]; for Columns 4 and 5, Khan [12], and for Column 6, [20]. Column 7 was calculated from: Muhammad [16] for 1965; Clark and Ghaffar [9] for 1968-69; [21] for 1975; and Chaudhary [2] for 1977-78. Column 9 was calculated from; [19] for 1966-67, Ahmad [1] for 1969; [21] for 1975, and [23] for 1979-80. Column 11 was calculated from: Muhammad [16] for 1965; [24] for 1972; Chaudhry and Ahmad [3; 4; 5; 6] for 1980-81. Finally, Column 13 was calculated from [19] for 1966-67; [21] for 1975; Chaudhry and Ahmad [3; 4; 5; 6] for 1979-80; and [26; 27; 28; 29] for 1980-81.

new wheat varieties was 76 percent, whereas the corresponding increase in yield was 127 percent. In the case of rice, the respective figures were a 21-percent increase in cost and a 42-percent increase in yield. Now, as regards trends in net returns, one can not be definite about them unless cost figures for all the years are available. But, in all probability, their trend must have been negative for two reasons: firstly, because gross returns as indicated by *YR* declined over time; and, secondly, because costs of modern inputs, such as fertilizers, which the improved varieties needed more, generally went up over time.

(ii) *Return from Tractors and Tubewells*

An ideal method of determining the farmer's gain from a machine would be to calculate both the increase in his production owing to a machine and the increase in his income from renting out its services. However, as stated earlier, since no such data are available, indirect methods are used to evaluate those gains. As our main interest here is to see the trends over time, we compare average prices of machines and the fuel used in them with the average per hour rental charges of their services. A comparison of the changes in these variables could throw some light on income from new technologies over time. But, one has to be careful in interpreting such changes, as not all items pertaining to income and cost have been covered here.

Columns (5) to (14) of Table 1 contain data on prices of tractors and tubewells as well as on indices of their rental charges for selected years. According to these estimates (which unfortunately are not very comprehensive), the average installation cost of a tubewell in the Punjab, which was Rs 8,700 in 1965, went up to Rs 12,000 in 1970-71, whereas the rental charges in that period increased only marginally from Rs 2.77 per hour to Rs 2.98 per hour. Again, in 1975, the cost of installing a tubewell in the Punjab as well as the price of diesel (used as an index of operating cost) increased much more than the corresponding increase in tubewell-rental charges. Between 1975 and 1982-83, when rental rates only doubled, diesel prices increased at least threefold.

The trend in the rate of return for tractors looks similar to that observed for tubewells. However, in this case, operating costs as well as purchase prices seem to have increased much more than rental charges. For example, the average prices of a tractor (with ploughs etc.) was Rs 12035 in 1966-67, which increased more than fivefold in 1979-80 (to Rs 67145), whereas its rental charges increased only three-fold (from Rs 7.78 to Rs 26.0) over the same period. Between 1966-67 and 1975, the price increased by 200 percent but the rental charges increased by only 80 percent. One of the reasons for this greater increase in the prices of tractors *vis-à-vis* those of tubewells could be a total elimination of subsidy on the former in recent years. Tubewells in Pakistan, however, continue to get some subsidy [14].

One of the major findings of Table 1 is that from all the new farm innovations (High-Yielding Seeds, tubewells and tractors), gains to farmers seem to have been high in the early years but went down with the passage of time.

B. Adoption of Technology by Farm Size in Pakistan

Now we try to examine the pattern of technology-adoption by farm-size in Pakistan, as, according to our theoretical framework in Section I, this is also an important determinant of the farmer's gains from new technologies. For this purpose, we use data mainly from the censuses of agriculture for 1960, 1972 and 1980[8] to calculate the following.

(a) *Percentage of farms growing HYVs.*

(b) *Percentage of cropped area reported under HYVs.* Whereas measure (a) reports only the incidence of the use of a new seed, measure (b) is meant to determine the magnitude of its use. A positive relationship of (a) and (b) with farm size would indicate that large farms used more of HYVs than the small ones.

(c) *Percentage of Farms Reporting Ownership of Tubewells, Tractors and Threshers/Shellers.*[9] It can scarcely be gainsaid that ownership of a machine by a farmer enhances his income prospects more than is possible with its use alone. Therefore, the higher the percentage of farms reporting ownership of a machine in a group, the greater the income prospects of that group.

(d) *Percentage Distribution of Tubewells, Tractors and Threshers/Shellers by Farm Size.* In conjunction with measure (c), this would show the extent to which ownership of farm machinery may have contributed to the wealth of farmers in different categories.

(e) *Percentage of Farms using Farm Machinery.* Since the use of machines could affect the overall agricultural productivity, we have also tried to examine the patterns of their use by farm size. But we must point out here that from the viewpoint of wealth distribution it is the 'ownership' which matters much more than simply the use of a machine.

(f) *Percentage of Farms using Fertilizers and Pesticides and Rates of Fertilizer Application by Farm Size.* Since fertilizers and pesticides play equally important roles in enhancing farm output, the pattern of their use should also be studied in assessing farm income and wealth.

[8] Wherever possible, other sources have also been used. See Tables 2 to 5 for those sources.

[9] Threshers and shellers are treated together here because this is how data are reported for them in the Pakistan Census of Agriculture [25].

For this purpose, we have estimated percentages of farms reporting use of fertilizers and pesticides as well as the 'quantity of fertilizer used' and the 'farm area fertilized' by them. Comparable data on the quantity of and area covered by pesticides were not, however, available.

All these estimates, for selected years from 1960 to 1980, are presented in Tables 2 to 5. The following are the main features of these results.

(i) *High-yielding Varieties of Wheat and Rice*

There seem to be three important trends in the adoption of HYVs. Firstly, there is little doubt that in the cases of wheat and rice large farmers used the improved seeds more than were used by small farmers in the early period. This is confirmed by both percentages of 'farmers reporting' and 'cropped area reported' under wheat and rice. For example, the percentages of farms reporting 50 percent or more area under improved wheat in Multan district in 1967-68 were between 15 and 26 on 'less than 25' acre farms and 38 for farms that were '50 acres and more'. In the case of rice, in 1972 the percentage of 'farms reporting' was between 12 and 59 for small farms but between 58 and 82 for large farms. Unfortunately, no data are available for pre-1972 period on 'cropped area' (under improved varieties). But looking at the 1972 data, one still finds that, compared with small farms, large farms devoted higher percentages of 'cropped area' to HYVs. For example, in the case of rice, whereas small farms devoted 12–46 percent of their area to improved (IRRI) varieties, large farms devoted as much as 43–61 percent of their area to those varieties.

Secondly, by 1980, HYVs became more or less equally popular among all farm groups. This, however, did not happen till 1972, when there were still significant differences in the adoption-patterns of different farm-categories. But even till 1980, the popularity of HYVs on small farms never exceeded that on large farms. For example, in 1980, large farms devoted 67–73 percent of the area under wheat to improved wheat varieties, whereas the percentage of wheat area devoted to improved varieties on small farms ranged between 54 and 68.

Thirdly, there are significant differences in the adoption-patterns for wheat and rice. Improved varieties of wheat seem to have become popular more rapidly than those of rice. In fact, adoption rate for IRRI rice by some of the categories declined in 1980 compared with 1972. This is particularly evident in the case of large farms and might have happened for two reasons.

(1) Rice crop needs more water to grow than wheat, and hence its new varieties were adopted mostly in irrigated areas. Improved varieties of wheat, on the other hand, spread to all types of areas, albeit with a varying degree of popularity.

(2) New varieties of (RRI) rice had to compete with two types of local varieties, of which *Basmati* was a fine variety and was preferred for consumption.

Table 2

Adoption of High-yielding Varieties of Wheat and Rice by Farm Size in Pakistan in Selected Years

Size of Farm	Wheat (Improved Varieties)						Paddy (Improved IRRI Varieties)					
	Farms Reporting				Cropped Area Reported		Farms Reporting				Cropped Area Reported	
	1967-68	1968-69	1972	1980	1972	1980	1972	1980			1972	1980
	(50% or more)											
Total (Private Farms)			58	68	52	69	31	45			42	50
Less than 1 Acre	NA	NA	49	53	50	54	12	37			12	35
Small Farms												
1.0 – 2.5 Acres	NA	NA	57	59		58		39				44
2.5 – 5.0 Acres				65	53	64	26	44			27	53
5.0 – 7.5 Acres	26	59	61	69	51	68	53	46			48	57
7.5 – 12.5 Acres	16	61		73	49	71	59	45			46	43
Medium Farms												
12.5 – 25.0 Acres	15	68	63	73	52	68	61	45			41	49
25.0 – 50.0 Acres	24	69	65	67	62	67	72	47			42	42
Large Farms												
50.0 – 150.0 Acres	38	79	73	62	58	73	58	52			43	44
150 + Acres			73	65			82	59			61	53

Source: Figures for 1967-68 and 1968-69 for Multan district of Pakistan are based on a study by Max Lowdermilk and are reported in Johnston and Kilby [11]. For 1972 and 1980, estimates are based on data from *Pakistan Census of Agriculture* [25] of the respective year.

N.A. = Data not available.

Table 3

Percentage of Farms Reporting Ownership (and use) of Tubewells. Tractors and Threshers/Shellers in Pakistan: Selected Years

Farm Size	Tubewells			Tractors			Threshers/Shellers		
	1960	1972	1980	1960	1972	1980	1960	1972	1980
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Total Private Farms	0.298	3.07	3.88	0.30	0.77	2.14	NA	NA	0.81
	(NA)	(28)	(36)	(NA)	(18)	(32)	(NA)	(NA)	(16)
Small Farms									
< 1.0 Acre	0.085	0.24	0.48		0.02	0.16	NA	NA	0.02
	(NA)	(16)	(44)	(NA)	(17)	(28)	(NA)	(NA)	(24)
1.0 – 2.5 Acres	0.141	0.48	0.63		0.06	0.26	NA	NA	0.04
	(NA)	(19)	(44)	(NA)	(20)	(28)	(NA)	(NA)	(17)
2.5 – 5.0 Acres	0.169	0.97	1.36		0.056	0.36	NA	NA	0.09
	(NA)	(22)	(35)	0.005	(16)	(31)	(NA)	(NA)	(17)
5.0 – 7.5 Acres	0.199	1.40	2.37		0.08	0.53	NA	NA	0.16
	(NA)	(25)	(31)	(NA)	(14)	(34)	(NA)	(NA)	(16)
7.5 – 12.5 Acres	0.307	1.93	3.18		0.19	0.94	NA	NA	0.30
	(NA)	(27)	(31)	(NA)	(14)	(34)	(NA)	(NA)	(15)

Continued –

Table 3 – (*Continued*)

Medium Farms									
12.5 – 25.0 Acres	0.499	4.13	6.28	0.09	0.54	2.75	NA	NA	0.98
	(NA)	(33)	(34)	(NA)	(18)	(35)	(NA)	(NA)	(15)
25.5 – 50.0 Acres	0.713	0.33	11.22	0.76	2.45	8.94	NA	NA	3.30
	(NA)	(41)	(41)	(NA)	(26)	(33)	(NA)	(NA)	(16)
Large Farms									
50.0 – 150.0 Acres	1.732	17.65	21.14	6.69	10.72	22.87	NA	NA	9.84
	(NA)	(44)	(51)	(NA)	(38)	(34)	(NA)	(NA)	(20)
150 + Acres	3.054	23.60	33.89	39.89	23.31	40.38	NA	NA	22.69
	(NA)	(39)	(58)	(NA)	(45)	(38)	(NA)	(NA)	(27)

Source: Estimates for 'ownership' for 1972 and 1980 are based on [25] whereas 1960 data for tractors are taken from Gotsch [10]. The data on use of machinery presented in brackets are taken from [25].
N.A. = Data not available.

Table 4

Distribution of Farm Machinery by Farm Size in Pakistan: Selected Years

(Percent)

Farm Size	Tubewells		Tractors				Threshers/ Shellers
	1972	1980	1960[1]	1972[2]	1975	1980	1980
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Total Private Farms	100.00	100.00	100.00	100.00	100.00	100.00	100.00
< 1.0 Acre	0.34	0.51		0.12		0.34	0.11
Small Farms							
1.0 – 2.5 Acres	1.39	1.93		0.81		1.51	0.69
2.5 – 5.0 Acres	4.16	5.41		0.99		2.75	1.84
5.0 – 7.5 Acres	6.85	9.47	1.00	1.52	4.20	3.97	3.13
7.5 – 12.5 Acres	14.34	17.18		5.78		9.60	8.34
Medium Farms							
12.5 – 25.0 Acres	26.45	26.17	4.00	14.00	11.08	21.64	20.49
25.0 – 50.0 Acres	22.46	18.53	15.00	23.54	23.74	26.37	25.86
Large Farms							
50.0 – 150.0 Acres	17.93	15.01	40.00	37.50	36.22	25.45	28.50
150.0 Acres & Above	6.08	5.78	39.00	15.74	24.77	8.50	11.01

Note: [1] Based on data from Carl Gotsch [10]; Census of Agriculture, 1972 & 1980 [25].
[2] Estimates based on data from *Pakistan Census of Agricultural Machinery, 1975* [21]. Other figures are based on data from [25].

Table 5

Use of Fertilizer and Insecticide by Farm Size in Pakistan

Farm Size	Fertilizer						Insecticide		
	Average Quantity (kg) per Acre			Cropped Area Fertilized (%)			(Percent of Farm using)		
	1960	1975-76	1980	1960	1972	1980	1960	1972	1980
Private Total Farms	44	70	49	NA	43	62	NA	2	4
< 1.0 Acre	42		54	NA	35	32	NA	2	1
Small Farms									
1.0 – 2.5 Acres	49		52	NA	42	48	NA	2	3
2.5 – 5.0 Acres	46	78	52	NA	42	55	NA	2	3
5.0 – 7.5 Acres	42		50	NA	42	60	NA	2	4
7.5 – 12.5 Acres	41	69	50	NA	43	63	NA	2	5
Medium Farms									
12.5 – 25.0 Acres	41	60	47	NA	43	63	NA	2	5
25.0 – 50.0 Acres	42		44	NA	41	63	NA	2	6
Large Farms									
50.0 – 150.0 Acres	63	75	48	NA	41	67	NA	3	10
150 Acres & Above	82		61	NA	49	72	NA	7	18

Note: 1. Data for 1960 refer to chemical manure.
2. Figures for 1975-76 refer to Punjab only and are taken from [17]. The other estimates are based on data from [25].

Therefore, IRRI varieties could not replace *Basmati* rice as much as the Mexi-Pak did the local wheat varieties.

(ii) *Tubewells, Tractors and Threshers/Shellers*

From the results on ownership and use of tubewells, tractors and threshers/shellers in Tables 3 and 4, there is little doubt that, in the beginning, large farmers had much more hold on them than small farmers. In general, those machines were concentrated in the hands of large farmers. However, an extremely important point which seems to emerge from these results is that by the time a particular machine became somewhat common, large farmers had moved on to a yet newer machine. In this way, they kept themselves ahead of small farmers. In the Sixties, for instance, tubewells were highly concentrated in the hands of large farmers: in 1960, 3.05 percent of all farms in the category of '150 acres and above' reported owning a tubewell, whereas in the 'small farms' categories this percentage was less than even 0.2. By 1972, in comparison with 1960, there was a considerably high percentage of 'medium farms' reporting the ownership of a tubewell, but now tractors were highly concentrated in the hands of large farms. Moving on to 1980, one finds that when, compared with 1972, tractors had become somewhat more evenly distributed, threshers/shellers (for which unfortunately earlier data were not available) became the favourite of large farmers. In 1980, 9.84–22.69 percent of farms in the 'large farms' category reported owning threshers/shellers, whereas this figure for small farmers was only around 0.02 percent.

As far as the use of these machines is concerned, it was much better than the ownership pattern. Large farmers, however, have continued to be in an advantageous position here also.

(iii) *Fertilizers and Pesticides*

The results relating to fertilizers and pesticides present a mixed picture. Looking at the 'farms reporting use of fertilizers', one does not find a significant difference in the behaviours of various farm categories. Compared with large farmers, a higher percentage of small farmers have reported using fertilizers. But the quantity of fertilizers used by large farmers appears to be more than that used by small farmers. In 1960, chemical manure used by large farmers amounted to 63–81 nutrient kg, whereas on small farms this quantity ranged from 41 to 49 nutrient kg. According to the data for the Punjab, collected by the National Fertilizer Company (NFC) in 1975-76, the quantity of fertilizers used by different farms was more or less uniform [17]. However, the data from the 1980 agricultural census do not confirm the NFC findings for Pakistan as a whole. The very large farms (150 + acres) have reported using much more quantity of fertilizers per acre than the quantity used by small farmers.

The situation with regard to the use of pesticides is different from that concerning fertilizers. The percentage of farms reporting use of pesticides was much higher for large farm than for small farms. In 1972, 7 percent, and in 1980, 18 percent of very large farms reported use of pesticides, whereas it was only 2 percent in 1972 and between 1 and 5 percent in 1980 for small farms.

III. SUMMARY AND CONCLUSIONS

This paper totally disagrees with the contention that small farmers in Pakistan, despite being financially weak and slow in adopting modern technology, have benefited relatively more from the Green Revolution because of their superior management practices and traditionally high productivity. Instead, it shows that if the rates of return from new technologies were such that they represented a decline over time and if large farmers were the first to adopt those technologies, then the large farmers must have benefited more than small farmers from the Green Revolution. This is so because large farmers, in contrast with the small ones, use a technology at a time when its rate of return is still high. If this behaviour is repeated over time, it must lead to a worsening of wealth distribution among farmers, even though small farmers are more efficient users of resources.

Using different indicators of profitability, we found that with the passage of time HYVs, tractors, and tubewells did not remain as profitable as they were in the beginning. We also observed that, in general, large farmers made more intensive and extensive use of technical advancements in the country. The use of fertilizers appears to be slightly more on small farms but that is not enough to show that they gained more wealth than large farmers from the total package of the Green Revolution technology.

An important conclusion of our analysis, therefore, is that in the existing policy framework, in which technology is made available to the farmer free of research and development cost and the government subsidizes modern inputs and provides institutional credit at concessional terms, large farmers would continue to benefit more from the technological advancements. However, their edge in this respect can be reduced if the diffusion of a technology is made more rapid and small farmers are provided special incentives to adopt technical changes at a time when they still offer good returns. Another method of reducing the wealth gap would be to transfer some of the gains made by large farmers from subsidized technology to small farmers through deliberate government actions. Drastic measures, such as altering "initial conditions", might also reduce this gap. However, one wonders why, as long as large farmers continue to have greater access to the newly available income-generating assets and the government policy continues to facilitate this process, this gap would not widen over time.

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Comments on "Wealth Effects of the Green Revolution in Pakistan"

Let me start off by saying that the subject has a high 'visibility' in the academic quarters and, I am sure, it will inspire an interesting discussion. Using proxy evidence, an attempt has been made to show that returns decline over time and that large farmers, assumed to be leaders in adoption, gained more than small farmers from the Green Revolution. Small farmers only earn competitive rates because they enter the technological domain with significant lag.

While the evidence reported in 1970 indicated that small farmers gained relatively less and adopted new technologies after large farms which did adopt and raised yields [4; 8; 9], the recent studies suggest a swing of the pendulum to the other side. It is being widely asserted that small farmers adopt modern varieties earlier and more intensively than large farmers [1; 5]. It has been reported that the adoption of modern varieties was widespread among farms, irrespective of size, by the late 1970s in Pakistan, Punjab, Bangladesh and Mexico [3]. Another study in a cotton-based farming system of Pakistan indicated that 60 percent of the farmers who adopted NAIB – 78 variety of cotton were small farmers [10].

It is easy to raise a number of perceptive questions: do small farmers adopt modern varieties? If so, when and on what proportion of the area, with how much supporting services and with what impact on farm income and efficiency? These are indeed interesting questions but their answers hardly reflect farmers' richness or otherwise, as size is a confusing variable.

Size gives little indication of farmers' capacity to generate income, as slope, terrain, water-logging, salinity, source of irrigation, soil erosion, location, rotations, cropping systems, crop-livestock farming systems, access to factor and product markets and information delivery systems and, above all, land tenure can make vast differences to scale. Farm classes (by size or income) differ substantially. It has been reported that adopters, despite having slightly less land per person than non-adopters, had significantly higher land value per person (2). It is, therefore, difficult to define a small farmer.

To be able to understand the impact of Green Revolution on small and large farms, one needs to follow a broad-based approach as the effect of innovations on crops at small farms depends on (i) adoption rate, (ii) proportion of land planted to improved variety, (iii) their access to other inputs, (iv) their capacity to saturate improved varieties with modern inputs, (v) prices received and paid, and (vi) yield realized. Other related variables are family size [7] and non-farm employment [6].

Small farmers have more hands to work (higher person/land ratio) and mouths to feed per acre. Hence, improved variety-fertilizer-irrigation technology should increase possibilities of generating higher yields and net income per acre on small than on large farms, provided their access to inputs, credit and extension is improved through appropriate policy designs. This prescription is based on the evidence that the so-called economies of scale of large farms arise not so much from their large size as from the politics of access to resources and government delivery systems.

With this sketchy and perfunctory overview of recent evidence, I turn to the operational framework of the methodology. Yield ratio is a poor and indirect (distant proxy) indicator of profitability. Here, one faces two conceptual problems. Firstly, in the case of wheat, not only has the upper quantity increased but the quantity in the bottom has improved considerably, too. While the yield from the local variety is fairly stable, the yield of improved variety is sensitive to changes in weather, water supply, and disease complex. Secondly, weeds, cropping systems in different farming systems and rotations, and, therefore, days to maturity have changed. It is plausible to argue that yield ratio has gone down not because of changes in potential response of wheat but because of a number of other micro factors, for example, late planting, cultivation of banned varieties, hard pan and sodicity in the soil, unbalanced use of fertilizers, and weed infestation. The researcher, in his excitement for the macro study, has last sight of its micro foundations. It is, therefore, appropriate to advise that, while looking for plausible explanations of the phenomenon under observation, micro foundations be given due attention.

Then, rice yield ratio has been shown to fall steeply and, by the year 1981-82, it starts edging upward. Again, an explanation is missing. Because of changes in pest complex and rotations, nutrient deficiency (such as zinc), and monopoly procurement of *Basmati* rice, the yield of local variety (*Basmati*) has drifted downward over the past 5-6 years. As a result, the denominator went down and, thus yield ratio increased.

Similarly, cost ratio has not been rigorously defined; that is the cost components and their computations have not been clearly stated. It is not clear as to how home-produced items of cost were treated. Note also that prices of tractors and fuel and hiring changes of tractors are determined under different market structures and, therefore, do not seem to stand on comparable grounds.

My last point relates to the title of the paper, "Wealth Effects ...." The title seems far from being consistent with the contents because wealth effect implies impact on consumption, savings, prices received, etc. The text, however, only makes a footnote reference to these highly relevant variables. Either the scope of the paper

should be expanded to include impact on these variables or the title should be matched with the present contents properly, if not tightly.

Social Sciences Division,
Pakistan Agricultural Reearch Council,
Islamabad

Mian M. Aslam

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