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The Adoption of Tubewell Technology in Pakistan

M. JAMIL CHAUDHRY*

The use and adoption of indivisible technology are not restricted by ownership or class structure. We have found, however, that in 1972, and still in 1980, though tubewells were owned by a minor fraction of total farm households (and predominantly by the large and medium farmers), they were used by a substantial proportion of farm households. Predictably, the user-owner ratio was the highest in the case of the small farmers in all provinces. The relative importance of the small and medium farmers as owners of this technology increased over the period, particularly in the Punjab where tubewells are concentrated.

The development of a hire market in tubewell services has given birth to a new entrepreneurial class in the rural areas. Inequalities in rural income are dwindling and benefits emanating from new technology are shared. These conclusions are of vital importance because they negate the existing views and show that (i) the indivisibility of technology has not been a barrier to its adoption, and that (ii) the fact that the share of the small and medium farmers in the ownership of tubewells has increased gives support to the thesis that if a technology is profitable, farmers will adopt it where possible. Thus, the view that small farmers are conservative and resist change can no longer be sustained. Further, it shows that the small and medium farm sector, in particular, holds the potential for investment in technology.

1. INTRODUCTION

The conclusions that emerge from the intercensal (1972–1980) examination of the adoption of tubewell technology run counter to some of the theorizing in the literature on this subject. Neither the indivisibility of technology nor risk aversion have been a serious constraint in the adoption of technology, particularly for small farmers, who have used it relatively more than their big counterparts despite the discriminatory treatment by credit agencies.

The main purpose of this paper is to document empirically the extent to which the adoption of tubewell technology has taken place. The analysis is undertaken at both national and provincial levels and, where data limitations permit, it is extended down to the farm household level as well.

The paper is divided into six major sections. Section 2 reviews the principal findings of the studies on the economics of tubewells in Indo-Pakistan subcontinent.

*The author is Assistant Professor of Economics at the University of Balochistan, Quetta.

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Its objective is to establish a meaningful background against which the problem under study can be viewed. Section 3 examines the development of tubewell technology at the national and the provincial levels. Section 4 analyses the adoption of tubewells by farm size at the national and provincial levels. Section 5 sheds light on the functioning of the tubewell hire market in Pakistan. The sixth and final section summarizes the conclusions.

2. PRINCIPAL FINDINGS OF THE STUDIES ON THE ECONOMICS OF TUBEWELLS

Ghulam Muhammad (1964) in his pioneering study found that installation of tubewells on a landholding resulted in multiple cropping, a manifold increase in fertilizer consumption, and more than double increase in the value of crops. He found tubewell investment highly profitable. Another study by him reinforced his earlier findings and, in addition, found that the use and efficiency of traditional and modern inputs increased after the installation of tubewells [Ghulam (1965)].

The studies of Falcon and Gotsch (1968) and Papanek (1968) largely confirmed the findings of Ghulam Muhammad. Moreover, they observed that the adoption of tubewells was aided by public policy, relatively higher and stable prices of crops, availability of cheap pump materials and electric connections. However, to Falcon and Gotsch (1968), the exact contribution of tubewells to the growth of aggregate GNP is difficult to measure because of the difficulties of separating the main effects of tubewells on cropping intensity, yield, and cropping patterns. Eckert has also argued that tubewells are non-homogeneous and, therefore, their contribution to total water availability is difficult to assess [Eckert (1974)].

The findings of Kaneda and Ghaffar (1970) were also consistent with earlier findings. They found that the major beneficiaries of tubewell technology were the farmers having land between 25–50 acres. Nulty (1972) found that in rice-growing areas the increase in net income of tubewell farmers ranged from 36–81 percent, while in cotton-growing areas it range from 61–104 percent. She too concluded that installation of tubewells was highly profitable.

While arguing that tubewells appear to be the most important single factor contributing to the Green Revolution, Alavi also pointed out that the Green Revolution would be a mixed blessing for Pakistan: while it might increase Agricultural output, it would also widen inter-farm and inter-Provincial disparities in income [Alavi (1976)].

In the case of the Indian Punjab, Saith (n.d.) found that tubewell irrigation was the fundamental factor influencing all the other components of technology (Fertilizer, HYV, Tractors). He concluded that though seeds and fertilizer in themselves were perfectly divisible, their application depended on controlled water supplies. Indeed, his empirical findings are in line with the arguments put forward by Falcon

(1970) that the adoption of HYV and the use of fertilizer associated with it depends on the prior availability of tubewells.

Bina (1985) has cited studies from the Indian Punjab which support the findings of similar studies in Pakistan. In her study, she concluded that tubewell irrigation has an advantage over canal irrigation and tubewell owners have an advantage over users.

Thus, the review of the literature on the economics of tubewells supports the contention that tubewells increase utilization of traditional and modern inputs. Consequently, tubewell farmers have an edge over non-tubewell farmers because they can control the amount and timing of irrigation, which is particularly important for the adoption of HYV and multiple cropping. These studies have clearly established the profitability of tubewell technology.

3. DEVELOPMENT OF TUBEWELL TECHNOLOGY IN PAKISTAN

The major sources of irrigation water in Pakistan are the canals and tubewells. Pakistan has the largest canal irrigation system in the world. It was initiated by the British long before the partition of the subcontinent. After partition the construction of a system of link canals with the help of the World Bank allowed a greater flexibility in the surface irrigation system. During 1960–65 many surface water projects came into being. By 1970, Mangla and Tarbela, the World's largest earth-filled dams, had been commissioned, substantially increasing the overall availability of water to the agriculture sector.

The adoption of tubewells was associated with the electrification of villages. In fact a major constraint on private tubewell development was the availability of electric connections. However, up to 1965 most of the tubewells installed were diesel-fuelled. These were more expensive to instal and operate than electric tubewells and their adoption was a second-best solution.

The demonstrated profitability to farmers, and especially the concentration of tubewells in the surrounding areas, forced the affected farmers to instal tubewells. The adoption became rapid because a concentration of tubewells often led to a localised lowering of water levels, so that it was no longer possible to lift water simply by using bullock power.

From a modest beginning in the early 1950s the number of working tubewells owned by private individuals was over 203 thousand by 1983-84 [Government of Pakistan (1975); (1983)].

In 1960, total water availability for the agriculture sector at the farm gate was 59 million acres feet (MAF) and at this time the contribution of private tubewells was 3 percent. By 1981-82, water availability at the farm gate increased to 100 MAF and the share of private tubewells in total water supply had increased to 25.7 percent, thus showing a ninefold increase over the previous two decades [Govern-

ment of Pakistan (1975); (1983)].

Development of Tubewell Technology in Provinces

The existing literature on the economics of tubewells has centred around Punjab because it is there that this technology is concentrated. Punjab also benefits from the largest canal irrigation system in the World, but all areas are not canal-fed. Moreover, even in canal-irrigated areas, uncertainty and unpredictability of canal water forced farmers to instal tubewells. The problems arose due to seasonal variations, and even more, due to malfunctioning of the distributive system, which is heavily weighted in favour of the landed aristocracy. Big farmers installed them to supplement canal water, while medium and small farmers installed them as a hedge against administrative bottlenecks – and they were also installed in areas where there were no canals.

Table 1 shows that in absolute numbers, most of the tubewells were and are concentrated in Punjab, which accounted for 88.4 percent in 1964-65 and 84.8 percent in 1982-83. In Sind, the ratio in the corresponding periods was 9.2 and 9.0 percent, respectively. In the NWFP the ratio in the corresponding period has increased from 1.0 percent to 2.5 percent. In Balochistan, the ratio was 1.4 percent, which grew to 3.7 percent in 1982-83.

The table also shows that, on the basis of cropped area, the number of tubewells has increased substantially in each province. The proportions of all the provinces except Sind have shown a substantial upward shift relative to Punjab. On this basis, there are now proportionately more tubewells in Balochistan, which overtook the Punjab in 1975.

Water is the major constraint for the development of agriculture in Balochistan. The most primitive and popular source of irrigation in Balochistan is through *Karezes*, a system of small underground channels. To construct and maintain these channels is a very expensive business: the region lies on an earthquake belt, and the deformation and speedy destruction of the *Karezes* takes place frequantly [Government of Pakistan (1974)].

The rapid development of tubewells in Balochistan must be seen in this perspective. That they replace *Karezes* is suggested by an examination of the data, which reveals that cropped area has not increased relative to the increase in the number of tubewells. The adoption of tubewells in Balochistan was rather late and very slow in the earlier years. In the early 1970s, Balochistan was connected with the National Grid system and the availability of electricity has increased the installation of tubewells.

Sind is mostly dependent on the canal irrigation system and tubewells play a lesser role. The explanation seems to be the prevalence of saline underground water which is not useable for cultivation. But wherever sweet water is available,

Table 1

Provincial Development of Tubewell Technology in Pakistan – by Province

Years	Punjab		Sind		NWFP		Balochistan		Pakistan	
	No. of Tubewells		No. of Tubewells		No. of Tubewells		No. of Tubewells		No. of Tubewells	
	Total (000)	Per Million Cropped Hectare	Total (000)	Per Million Cropped Hectare	Total (000)	Per Million Cropped Hectare	Total (000)	Per Million Cropped Hectare	Total (000)	Per Million Cropped Hectare
1964–65	28.75	2705	2.98	835	0.33	248	0.47	652	32.53	2003
1968–69	53.80	4995	3.68	1003	0.77	562	1.07	2598	59,32	3653
1972–73	108.39	9217	5.83	1794	1.97	1263	3.09	8583	119.28	7045
1975–76	144.18	11847	8.37	2256	3.70	2033	4.71	14719	160.96	8932
1981–82	176.89	13503	17.36	4451	5.23	2922	7.58	14862	207.06	10728
1982–83	181.89	13880	19.31	4950	5.40	3020	7.85	15392	214.45	11110

Sources: These calculations by the author are based on:

(i) [Chaudary and Malik (1981), p. 58] (1964-65 to 1968-69) data for tubewells.

(ii) Government of Pakistan (1975) and (1983).

Note: These Tubewells include public tubewells.

people instal tubewells; and that is evident from a sixfold increase in the number of tubewells.(See Table 1).

The NWFP also relies on the canal system, but one of its important characteristics which differentiates it from others is the level of heavy rainfall. However, in areas where canal irrigation is not available, or to supplement it, farmers have installed tubewells, mainly in the 1970s.(See Table 1).

The growth rates vary from province to province. During 1964-65 to 1981-82, the annual growth rate in the Punjab was 11.3 percent (of course from an ever-growing base), for Sind it was 10.9 percent, and for Balochistan and the NWFP it was 17.8 and 17.6 percent, respectively. Similarly, the growth rates of tubewells on a per cropped hectare basis were 20.2, 15.6, 10.3 and 9.9 percent in Balochistan, the NWFP, Sind, and Punjab, respectively.

Thus tubewell technology in absolute terms was highly concentrated in the Punjab in 1964-65, but it was also penetrating other provinces of the country. The relative share of the Punjab has declined and the rate of growth of tubewell installation on a per cropped hectare basis has been faster in all other provinces than in the Punjab. This clearly shows that the regional disparity in the concentration of this technology has gradually decreased.

4. ADOPTION OF TUBEWELL TECHNOLOGY AT FARM LEVEL

The following discussion is based on the Census of Agriculture 1972 and that of 1980. It is unfortunate that the 1972 census excludes the Kalat district of Balochistan and the 1980 census excludes Balochistan altogether. The damage to our analysis, however, is limited by the fact that Balochistan is in some respects the most backward of the provinces of Pakistan and cannot have accounted for more than 4 percent of the tubewells in the rural economy. Thus, our data provides information at the national level, on nearly 96 percent of private tubewells in the rural economy of Pakistan. To facilitate intercensal comparisons, Balochistan has been excluded from Pakistan in both sets of data.

Table 2 shows changes in the proportion of owners and users of tubewells during the intercensal period. In 1972 the proportion of farm households (FHH) which reported the ownership of tubewells in Pakistan was 3.2 percent. In 1980, this proportion grew to 4.08 percent. On the other hand, the proportion of FHH which used tubewells in 1972 was 29.1 percent; and in 1980 this was 34.13 percent. Comparing the proportions of owners in the respective categories of FHH in 1972 with those in 1980 we note, though, that the proportions of all FHH have shown improvements but the medium and the small have gained relatively more.

Looking at the data from another perspective (Table 3), we note that in 1972 the share of small farms in the ownership of tubewells was 27.2 percent, and of medium and large farms was 26.5 percent and 46.3 percent, respectively.

Table 2

Owners and Users of Private Tubewells in Pakistan and its Provinces – by Farm Size

	Tubewells (1972)		Tubewells (1980)	
	Owners %	Users %	Owners %	Users %
Punjab				
Small Farms	2.1	38.3	3.11	49.16
Medium Farms	5.7	46.3	8.72	47.80
Large Farms	16.1	57.3	20.93	47.10
All Farms	4.6	42.4	5.95	48.70
Sind				
Small Farms	0.12	2.06	0.31	6.79
Medium Farms	0.47	3.30	0.59	5.83
Large Farms	4.40	8.65	2.85	7.47
All Farms	0.51	2.82	0.55	6.68
NWFP				
Small Farms	0.20	2.21	0.21	4.70
Medium Farms	1.09	7.70	1.11	8.14
Large Farms	2.10	13.31	1.91	9.56
All Farms	0.41	3.47	0.37	5.22
Balochistan				
Small Farms	0.20	1.61	Not Available	
Medium Farms	0.59	2.94		
Large Farms	1.30	3.17		
All Farms	0.54	2.25		
Pakistan				
Small Farms	1.4	24.8	2.06	33.11
Medium Farms	4.3	34.7	6.64	37.03
Large Farms	13.2	46.3	16.17	37.01
All Farms	3.2	29.1	4.08	34.13

Source: These computations are based on data given in the Pakistan Census of Agriculture 1972 and 1980. [Government of Pakistan (1972) and (1983a)].

Notes: (i) These are proportions of owners and users in total farm households.

(ii) Pakistan figures for 1972 and 1980 exclude Balochistan.

Table 3

Ownership of Tubewells – by Size of FHH

Type of Farm Household	Tubewell Numbers 1972	Tubewell Numbers 1980
Punjab		
Up to 12.5 Acres	32866	57108
12.5 to 25 Acres	32153	44260
Above 25 Acres	53914	65722
All Households	118933	167090
Sind		
Up to 12.5 Acres	680	1871
12.5 to 25 Acres	843	798
Above 25 Acres	3866	2013
All Households	5389	4682
NWFP		
Up to 12.5 Acres	796	1036
12.5 to 25 Acres	494	468
Above 25 Acres	834	657
All Households	2124	2161
Balochistan		
Up to 12.5 Acres	202	N.A.
12.5 to 25 Acres	243	N.A.
Above 25 Acres	659	
All Households	1104	
Pakistan		
Up to 12.5 Acres	34342	60015
12.5 to 25 Acres	33490	45526
Above 25 Acres	58614	68392
All Households	126446	173933

Source: Pakistan Census of Agriculture 1972 and 1980. [Government of Pakistan (1972) and (1983a)].

Note: Figures for Pakistan exclude Balochistan, for tubewells in 1972 and 1980.

Comparing the above proportions with those in 1980, we note that only the small farms' share increased from 27.2 to 34.5 percent. Medium farms nearly maintained it, while the proportion of large farms declined to 39.3 percent.

Thus the data shows that though in 1972, and still in 1980, tubewells were owned by a minor fraction of the total FHH – and in that minor proportion they were relatively owned mostly be large and medium FHH – yet (i) they were used by a substantial proportion of FHH and (ii) the ownership was also filtering down from the large to the small farms.

Provincial Adoption of Tubewell Technology by Farm Size

Punjab is the heartland of Pakistan. It dominates other provinces in every respect and clearly dictates the national trend.

In 1972, the Punjab had 94 percent of the 126.45 thousand tubewells in Pakistan. Out of this, 27.6 percent were owned by small farms, 27 percent by medium farms, and the share of the large farms was 45.3 percent. In 1980, the Punjab's share was 96.1 percent. The ownership by small farms increased to 34.2 percent. Though in absolute terms the medium and the large farms gained too, yet their share declined.

Comparing the share of owners and users in 1972 with those in 1980, we note that the ownership proportions among different sizes of farm household vary widely, but the proportion of users appears to be independent of farm size. And looking at the data we observe that the Punjab is the only province where more than 42 percent of the FHH in 1972 and 48.7 percent of FHH in 1980 have reported its use. While in the case of all other provinces this ratio in 1972 was around 3 percent, and in 1980 has not exceeded beyond 7 percent for all FHH (Table 2).

Thus we can conclude that in the case of the Punjab, where this technology is highly concentrated, indivisibility of technology has not been a major constraint on the adoption of technology in the case of small farmers. They adopted electric tubewells relatively more than the others during the 1970s at least, and their relative share in the ownership of tubewells has increased.

Table 2 shows that in 1972 the ownership and use of tubewells in Sind was mostly concentrated in large farms. By 1980 the share of ownership by small farmers had increased substantially, the medium farms had also gained and the share in ownership of the large farms had declined. Not only the proportion of owners has shown a shift towards the small and medium farms but also, as far as the use is concerned, small owners are using them relatively more than their big counterparts.

Looking at the data from another perspective, we note that in 1972, Sind had 4.3 percent of the 126.45 thousand tubewells, but in 1980 this ratio declined to 2.7 percent. The share of small farms in the ownership of tubewells was 12.62 percent, the medium and large farms respectively had 15.6 and 71.7 percent. In

1980 the proportion of ownership changed to 40.17 and 43 percent, respectively.

This shows that the pattern of ownership has shifted towards small farms. Medium farms have also gained, the proportion of large farms in ownership has declined. Before we comment on this situation, the data published in the 1980s agricultural census shows a decline in the total number of working tubewells *vis-a-vis* 1972. Because the data in both censuses relates to the private working tubewell, it may be gathered that the decline in the absolute number of tubewells may be due to the reason that large numbers of tubewells may have become unuseable over time, or that they were not in serviceable condition at the time of enumeration, or were taken out of service where underground water was found to be saline. (The number of tubewells owned by non-farm households during this period increased from 652 to 956).

Thus, in the case of Sind, there has been a substantial shift in the proportions of users (particularly small farmers) – from 2.82 to 6.68 percent of the FHH. This shift has been in the case of small FHH, which is obvious from the fact that 77 percent of the FHH among total FHH users were small farms.

In the case of NWFP, intercensal comparison shows that the share of large farms declined from 2.1 percent to 1.91, while that of the medium farms has increased and of small farms has remained unaffected.

But when we compare the proportions of users, we find that in the case of small farms the proportion has more than doubled, medium farms have also shown improvements in their proportions, and the share of large farms has dwindled (Table 2).

Thus it appears that there has not been a visible increase in the ownership of FHH-owning tubewells. But this fails to take account of the changes in the number of FHH during the intercensal period: the number of small farms increased from 391 thousand to 459 thousand. If we look at the data from the ownership point of view, it will provide a better perspective. As Table 3 shows in 1972, 37.48 percent of the small farms, 23.26 percent of the medium farms, and 39.20 percent of the large farms owned tubewells. In 1980, 47.94 percent of the small FHH, 21.66 percent of medium FHH, and 30.40 percent of large FHH owned tubewells.

Thus the data shows that in the intercensal period, small FHH have gained in terms of ownership. Their share in the use of tubewells has increased tremendously, and this is reflected by the fact that 78 percent of the FHH within tubewell users were the small farms.

In 1972, Balochistan's share in the total number of private tubewells in Pakistan was less than 1 percent .60 percent of these tubewells were owned by large FHH, 22 percent by medium FHH, and 18.0 percent by small FHH (Table 3). Looking at the share of owners and users we come to the same general conclusion which we have arrived at in the case of the other provinces: that tubewells were

owned by a very small fraction of the FHH, but they were used by each and every class of FHH proportionately more.

The Agricultural Census 1980 failed to provide information in the case of Balochistan. Therefore, we were unable to gauge the changes at the regional level by farm size.

However, in the previous section, we had observed that tubewell technology was spreading rapidly in Balochistan and, on the basis of per cropped hectare, the number of tubewells was highest there. Hence it would be quite reasonable to assume that, at farm level, Balochistan might have behaved in the same way as other provinces have done.

5. THE TUBEWELL HIRE MARKET IN PAKISTAN

Tubewell installation entails fixed costs which are not justified in the case of very small farmers, and most of the small and even some of the middle class farmers are not financially able to instal them individually. In general, tubewells are installed in partnership with others. Those who are not able to do this hire tubewell services from the owner, and this has given birth to a customary hire market for tubewells in every province of Pakistan. There are broadly two ways to charge the price of water:

(i) *Fixed Proportion of the Produce.* When the harvest is ready, a fixed proportion of the produce is taken out and is termed the "share of water". This is normally 1/3rd for rice and *berseem*, and 1/4th for all other crops. In the case of some crops, if it is not physically possible to weigh the crops, the area on which the crop is standing is apportioned accordingly and the tubewell-owner has the right to sell the crop to anybody, giving first preference to the owner of the land;

In this system, the agreement remains in force throughout the agricultural year irrespective of whether the tubewell service is actually used. This kind of market operates in a limited radius and water supply is normally denied to farmers who live beyond this radius or whose land lies in a particular direction where the ascent of the water is difficult; and

(ii) *Cash Payment.* The latest development in the hire market appeared in the form of an agreed amount per hour for the running of the tubewell. This system is a hedge against the increasing cost of electricity, cost of diesel fuel, and falling crop prices. This system is only for users, and is normally in operation in those areas where canal water is already available. In the case of joint owners of tubewells, the 'fixed proportion of the produce' system is applicable. After deduction of running expenses, income is shared on the basis of initial investment at the time of installation of tubewells.

6. CONCLUSIONS

The use and adoption of indivisible technology are not restricted by ownership or class structure. There are farm households in the highest ladder of landholding which wish to assert their social status or themselves achieve maximum utilization and so will not hire tubewell services to others.

We have found, however, that in 1972, and still in 1980, though tubewells were owned by a minor fraction of total farm households (and predominantly by the large and medium farmers), they were used by a substantial proportion of farm households. Predictably, the user-owner ratio was the highest in the case of the small farmers in all provinces. The relative importance of the small and medium farmers as owners of this technology increased over the period, particularly in the Punjab where tubewells are concentrated.

Though the share of the other provinces has increased, tubewell technology remains concentrated in the Punjab, where the proportion of the farm households that reported the use of tubewells rose from its 1972 level of 42 percent to 49 percent in 1980. In the rest of Pakistan the proportion of the farm households using tubewells remains very low. Despite the massive installations of the period, it was still only 7 percent in 1980.

The development of a hire market in tubewell services has given birth to a new entrepreneurial class in the rural areas. Inequalities in rural income are dwindling and benefits emanating from new technology are shared.

These conclusions are of vital importance because they negate the existing views and show that (i) the indivisibility of technology has not been a barrier to its adoption, and that (ii) the fact that the share of the small and medium farmers in the ownership of tubewells has increased gives support to the thesis that if a technology is profitable, farmers will adopt it where possible.

Thus, the view that small farmers are conservative and resist change can no longer be sustained. Further, it shows that the small and medium farm sector, in particular, holds the potential for investment in technology.

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