Transformation of Groundwater Market in Bengal: Implications to Efficiency and Income Distribution

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1. INTRODUCTION

The rapid agricultural growth since the early 1980s experienced in the lower Gangetic basin of the Indian subcontinent brought about a drastic rural change and reduction of poverty in the region. The engine of growth was the diffusion of private shallow tubewells (STWs) for irrigation. The Bengal, consisting of West Bengal, India and Bangladesh, where the agricultural sector had been largely stagnant for a long period until the end of the 1970s (Boyce [1986]), was not the exception of such a rapid rural transformation (Rogaly, et al. ed. [1999]), although the diffusion of tubewells lagged behind for nearly two decades compared to the advanced agricultural regions such as Punjab.

It has been argued that the backwardness of the lower Gangetic region in terms of tubewell irrigation development is basically attributable to its agrarian structure characterized by the overall small farm size with extreme fragmentation of land (Bardhan [1984]), but what actually happened after the 1980s was the very diffusion of tubewells without development of land consolidation projects. The key phenomenon was the emergence of a rental market for inputs with scale economy; i.e. market for groundwater in the case of tubewells. In this sense, it can be safely said that the emergence and development of such a groundwater market did contribute to the widespread and rapid agricultural and rural economic development in the region.

However, since the groundwater market is characterized as a highly segmented market, where usually a few rich farmers sell water to a large number of poorer farmers, its implication to rural income distribution has been paid serious attention among researchers.[1] The high profit rate realized in tubewell investment, especially under the crop sharing arrangement in water sales (one-fourth of harvest accrued to water sellers, in many cases), strengthened the argument of the emergence of 'waterlords' in rural areas instead of the traditional landlords. The problems of exploitative relationship developed between tubewell owners and non-owner farmers in interlinked transactions in water and other inputs also were raised.

Efficiency issues of the market have also been addressed. The performance of the market in terms of productivity differentials of land between tubewell owners and non-owner farmers has been one of the most important issues. It is notable in this regard that Dubash [2002] recently showed how the groundwater market is problematic in its functioning, leading to large productivity differentials, as against the former arguments of supporting the efficient market hypothesis such as Meizen-Dick [1996], Shah and Ballabh [1997], and Kurosaki [1999].

In sum, discussions on groundwater market have been widely done in India and the surrounding countries, especially from the viewpoint of its efficiency and equity implications. However, so far, the empirical studies on groundwater market have been, by and large, concentrated in examining the market structure at one particular time. Dynamic transformation of the market has been relatively neglected. Considering the fact that the structure of groundwater market did experience a substantial change under increasing density of tubewells in a confined area, investigation should be conducted more from a dynamic viewpoint rather than a static one. It is plausible that the efficiency and equity implications of the market have also been changed according to the transformation of the market itself.

The purpose of this paper is to examine such a dynamic change of groundwater market and to draw implications from it. The study is based on primary data collected in several selected villages

[1] See, for example, Bangladesh Agricultural University [1985] [1986], Wood and Palmer-Jones [1991], Pant [1992], Janakarajan [1992], Kahnert and Levive [1993], Shah [1993], Shah and Ballabh [1997], Meizen-Dick [1996], Kurosaki [1999], and Dubash [2002].

in the Bengal region, where the author conducted intensive surveys during the last decade.

The composition of the paper is as follows: In section 2, the structure of groundwater market in a study village in Bogra, Bangladesh in the year 1992 is briefly presented.[2] In section 3, results of a re-survey in 1999 in the same area in Bangladesh are shown and the structural change of groundwater market between the two periods is discussed. In section 4, based on a village survey in 2000, the emergence and transformation of groundwater market in West Bengal, India is presented, where comparison with the case of Bangladesh is stressed.[3] Finally in section 5, as concluding remarks, the evolution of groundwater market in Bengal and its implications are summarized.

2. GROUNDWATER MARKET IN BANGLADESH IN THE 1980s

The development of irrigation in Bangladesh was minimal until the mid-1950s, when only 5% of land was under irrigation and the major irrigation method was manual.[4] The mechanical irrigation started to be introduced gradually since the early 1960s by deep tubewells (DTWs) and low lift pumps (LLPs), utilizing groundwater and surface water respectively. In particular, surface water irrigation by LLPs spread widely, although still limited in the southeast regions such as Comilla. It was not until the late 1970s when groundwater irrigation developed remarkably by the diffusion of private STWs.

The rapid dissemination of STWs was induced by a series of deregulation policies of agricultural input market started since the late 1970s. It was further accelerated by the sharp decline of the price of diesel engines (for STWs), which was induced by the import liberalization measure announced just after the devastating flood in 1988. Tubewell diffusion was particularly remarkable in northwest Bangladesh where groundwater resources were plentiful. Many dealers of STWs emerged and concentrated in Bogra, one of the major towns in northwest Bangladesh.

Village A, one of the study villages, is located in the Bogra district. It is on a diluvial plateau called Barind tract and is therefore free from the regular floods (Map 1). The Barind tract used to be a single cropped area of *aman* (transplanted), major rainy season rice in Bengal, but the development of groundwater irrigation since the 1980s totally changed that situation. Village A was not the exception, where the diffusion of private diesel STWs drastically changed its cropping pattern from the single cropping of transplanted *aman* to the double cropping of rice (transplanted *aman* and *boro*[5]). At the same time, high yielding varieties (HYVs) started to diffuse, with an application of chemical fertilizers. In 1992 when the author first conducted an intensive survey in Village A, more than 90% of land was already covered under irrigation. In the irrigated area, the major crop during the dry season was *boro*, with a very minor exception of a kind of vegetable locally called *khira*.

Table 1 shows the distribution of farmland among households in the village. Land distribution was highly skewed and nearly half of the households were landless, whereas only 34 (16% of total) households occupied nearly 80% of land. Landless people relied mainly on agricultural hired labor, because off-farm job opportunities were extremely limited. In 1992 the number of STWs reached 30, which already covered more than 90% of farmland as mentioned above. Lastly and most importantly, it should be noted that the distribution of STWs was skewed in favor of large and rich farm households.

1) Mode of Water Transactions

There were in total 30 diesel STWs owned by the villagers in 1992 and 307.6 acres of land were irrigated in the dry season, mainly for *boro* cultivation. The command area of each tubewell varied between 5.4-20.0 acres, with an average of 10.3 acres. Most of the STWs were attached with 6 horsepower diesel engines.

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[2] Details were already reported in Fujita and Hossain [1996].

[3] Details were reported in Fujita, Kundu and Jaim [2002].

[4] Traditional instruments such as *doon* and swing basket were utilized for lifting water to paddy fields.

[5] *Boro* is the dry season rice in Bengal, which was traditionally grown in the lowest land where water for irrigation is available even in the dry season.

The contractual arrangements in water transaction could be classified largely into three.

The first was STW owner's owned and self-cultivated land, in which exchanged land among STW owners, although not large, was also included. Thirty-five (35) percent of land was under this category. The second was the land leased-in on a seasonal basis by STW owners. Under this seasonal tenancy system locally called *Chaunia*, 3 *maund* (1 *maund* =37.3 kg) of paddy per *bigha* (1 *bigha* =1/3 acre) had to be paid as land rent. Note that the average yield of *boro* was about 13 *maund* per *bigha*, so that the land rent amounted to about 23% of gross output. Approximately 42% of irrigated land was under this category and was the largest.

The third was water sale to farmers, occupying 24% of total. It could be further subdivided into three systems according to the mode of payment of irrigation charges; i.e. fixed cash payment, crop-share, and the mix of cash payment with crop-share. Under the cash payment system, water buyers were requested to pay in advance a fixed amount of cash, ranging 2,100-2,400 taka per acre. In the case of crop-share, the share accruing to STW owners was either 33% or 40%. Among 11 cases observed, 6 paid 33% and the remaining 5 paid 40%. If converted into monetary terms the payments ranged 3,000-3,500 taka per acre. The last mixed system means that a portion, usually 300 taka per acre, was paid in advance and the remainder was paid by the share of harvested paddy, usually 33%. STW owners were responsible for digging irrigation channels every season for water buyers.

2) Estimates of Profitability of STW Investment

Table 2 summarizes the cost and return of STW operation, especially for the case of water sale. Cost of irrigation comprises O&M cost (operation & maintenance cost: diesel oil, lubricant oil, spare parts and service charge for repair, and labor) and depreciation cost of facilities. The latter was estimated by the constant amount method, assuming a life of ten years for new Japanese engines and five years for others (second-hand Japanese and new Korean or Chinese). The total average cost was estimated 1,606 taka per acre. Water charge, on the other hand, was estimated 3,210 taka per acre on an average.

The estimates of w/c (w =water charge per acre, c =O&M cost per acre) and w/ac (ac =total average cost per acre) are shown in the table. The value of w/c, a good indicator of the 'monopolistic' degree of groundwater market,[6] for individual STWs ranged between 1.13 and 6.18 with an average of 2.59. Given the fact that the value of w/c (average) is ranging from 1.16 to 2.53 in the other case studies in Bangladesh,[7] it can be concluded that the case of Village A recorded a very high value.

Next let us examine the profitability of STW investment from another point of view.

Net irrigation surplus (NIS) can be defined as the surplus, in which all the costs except for land rent and interest for working capital are deducted from gross production of irrigated *boro*. In theory, NIS is composed of land rent, interest on working capital, and profit (for STW investment).

Table 3 demonstrates the estimates of total NIS generated in the village in the year 1991/92. It is found that the total was approximately 1.3 million taka, 21%, 15%, 64% of which was distributed to 'landowners' (who owned land but rented it out to STW owners under *Chaunia* arrangement), 'farmers' (water buyers), and STW owners, respectively.

The question now is how NIS can be decomposed into returns to various production factors such as land rent, interest for working capital, and profit (for STW investment). Table 3 already shows the

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[6] According to Shah [1993], profit (P) that accrues to STW owners is defined as follows.

$$P = wA - cA - F,$$

where A is the land area to which water is sold (assuming that all the water is sold), w is the water charge per acre, c is the O&M cost per acre, and F is the fixed capital cost during one irrigation season (depreciation cost of STWs). Now assuming that water sellers hold a monopoly and their behavior is to maximize profit, the equilibrium water charge w* is obtained as follows.

w* = *e*/(*e*_1)_c,

where *e* represents the price elasticity of demand for water.

Thus we get w/c = e/(e_1), which can be a good indicator of 'monopolistic power' of STW owners in the groundwater market.

[7] See Fujita and Hossain [1996] for details.

result of decomposition.

The procedure of decomposition is as follows. First, the surplus accrued to 'landowners' can be regarded as pure land rent. The land rent is, as already reported, 3 *maund* of paddy per *bigha*, which can be converted into 2,064 taka per acre. By using this rate, the portion of land rent can be separated from NIS that was distributed to 'farmers' and STW owners. Second, given that the short-term interest rate most frequently observed in the village informal credit market was 100% per annum, and assuming two-month borrowing period on average for *boro* production, the amount of interest for working capital can be estimated and separated. The result in the case of 'farmers' shows that the remaining amount after deducting the interest (for working capital) is only 2,052 taka, close to zero, which indicates the validity of the estimates. Third, by the same token, the NIS accrued to STW owners can also be decomposed. It is evident from the table that a substantial part of the NIS that STW owners obtained was nothing but a profit for their investment in STWs.

Figure 1 illustrates the factor share distribution for irrigated *boro* production in the village. It also shows how NIS is distributed between STW owners and non-owners under different contractual arrangements. Under the seasonal tenancy (*Chaunia*), non-owners can get only land rent. If they purchase water and cultivate land by themselves, they can also get interest for working capital, besides land rent. Note that in the case of cash payment they can get larger income compared to crop-share because they have to pay water charge in advance, meaning that they also bear working capital for irrigation, so that they get return from it.

3) Emergence of Waterlords?

Now the critical issue is whether the profit that STW owners obtained was 'exorbitantly' large or not. Figure 2 shows the amount of surplus captured by STW owners, in relation to the achieved irrigated acreage. The rate of return to STW investment can be estimated by dividing the surplus by initial invested value. Although scattered very widely, 69% was the average rate of return.

In the study village there is a long-term land tenancy system locally called *khaikhalashi*, where an advance payment of 10,000-15,000 taka per acre makes it possible for the payer to cultivate the land for seven years without additional payments. Estimates by the author indicate that the land rent (operators' surplus) is about 6,354 taka per acre per year, so that the rate of return for investment in *khaikhalashi* is on average 50%, ranging 38-61%.

Thus it is concluded that the rate of return to STW investment (69%) was higher than the other major investment opportunities in the village (*khaikhalashi*: 50%), though both are not significantly different. The factor share of land in rice production, which formerly occupied 30-50% of gross produce, declined sharply to only about 22% (see Table 8). Needless to say, the major part of the decrease in the factor share of land was absorbed by STW owners. Water sellers, in this sense, may deserve to be called 'waterlords'.

In sum, the investment to STWs was fairly a good opportunity for rich farmers, at least until the end of the 1980s. However, the situation rapidly changed afterwards, which was revealed in 1999.

3. TRANSFORMATION OF GROUNDWATER MARKET IN THE 1990s

In 1999 after seven years from the first survey in Village A, a survey on groundwater markets was again conducted in the same rural area in Bangladesh. In total three villages including Village A were covered in the survey.

Table 4 shows how the situation on groundwater irrigation experienced a drastic change during the several years. Village B was selected for study because reliable data on groundwater market were available for the year 1987 (Ando, Rashid, and Kaida [1991]). It is clear from the table that in both of the villages, although irrigation had already covered more than 90% of land at the end of the 1980s or the beginning of the 90s, a large number of STWs were further introduced, reaching nearly double or more by the year 1999. As a result, the average command area of STWs sharply reduced from 10-12 acres to 6-7 acres.

The phenomenon was not limited to the study site. Close examination by the author on official statistics related to irrigation in Bangladesh shows that an apparent decreasing trend of average command area of STWs was observed for the whole country during the 1990s, because of the increased number of them in a confined area.[8]

What happened in groundwater markets in Bangladesh during the 1990s? Let us now examine this issue more closely, based on an intensive survey in the third study village in Bogra district.

The study village (Village C) is also located on Barind tract and is free from regular floods. It is located along the national highway and blessed with good infrastructure (Map 1). The village had 194 households and 201 hectares of farmland in 1996.[9] In 1999 when we conducted an in-depth survey, there were in total 2 DTWs[10] and 24 STWs. The DTWs were electrified, while most (22 out of 24) of the STWs were still diesel-operated. Large farm households with more than 2.5 acres owned most of the tubewells, the same situation as Village A and B.

Table 5 shows the process of the diffusion of tubewlls in the village. By 1991 and 92 when the two DTWs were introduced, groundwater market in the village was nearly saturated already. However, not a negligible number of STWs were newly installed since then. As a result, the average command area of STWs was decreased to only 6.1 acres. The major cropping pattern was double cropping of rice (*aman* followed by *boro*), but there practiced a triple cropping (*aman*- potato/ mustard- *boro*) in a part (about 15%) of farmland. Irrigation was necessary not only for *boro* but also for potato and mustard, although to a lesser degree.

1) Change in the Mode of Water Transactions

In 1999 the total irrigated acreage by tubewells reached 267 acres of *boro*, 37 acres of potato/mustard, and 2 acres of the other crops. Various contractual arrangements were observed in the village, which could be largely classified into three; (1) owned (including temporarily exchanged) and self-cultivated land of tubewell owners, (2) rented-in and/or mortgaged-in land by tubewell owners, (3) water sales. Note here that the second category was different from the seasonal tenancy called *Chaunia* found in Village A, in which land rent was paid in kind after harvest. The tenancy in Village C was classified into seasonal one (called *potton*) and yearly one (*sonpotton*), in both of which land rent was paid in cash in advance.[11] In the water sales transactions also, only the system of fixed cash payment per acre (in two installments) was observed, without finding any cases of crop-share.

In the case of *boro*, the major irrigation crop in the village, the share of different modes of water transactions was as follows; i.e. 17% (45 acres) for owned and self-cultivated land by tubewell owners, 13% (35 acres) for rented/mortgaged-in land by tubewell owners, and 70% (187 acres) for water sales. In the case of potato/mustard, on the other hand, the same figure was 43%, 24%, and 32%, respectively.

In sum, the major contractual arrangement in the village was water sales with in-advance cash payment, a sharp contrast with Village A in 1992, where the dominant modes were *Chaunia* and water sales with crop-sharing. However, it should be noted here that in Village A also, by the year 1999, *Chaunia* has already vanished and water sales with in-advance cash payment were predominant. It can be said that such a drastic change in the dominant mode of water transactions took place in rural areas in Bangladesh during the 1990s.[12]

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[8] The trend of irrigated area in official statistics, which is estimated by multiplying the number of tubewells with a fixed command area per one tubewell, apparently differs from the statistics of the irrigated area based on crops. This is because of the sharp decline of the average command area of tubewells (see Fujita [2001] about details). For further evidence, see also International Irrigation Management Institute with the Bureau of Socio-Economic Research and Training of the Bangladesh Agricultural University [1996].

[9] For the purpose of the evaluation of Grameen Bank housing loan, OECF (Overseas Economic Cooperation Fund) in Japan, now reorganized and re-named as JBIC (Japanese Bank for International Cooperation), selected Village C as one of the research sites. The author participated in the research project.

[10] DTWs were sold to individual farmers by BADC (Bangladesh Agricultural Development Corporation) at a highly subsidized price. Farmers installed them in the village after getting them from BADC.

[11] The mortgage arrangement popular in Village C was *khaikhalashi*, same as in Village A.

[12] Note, however, that no such a change was observed in Village C, where *Chaunia* and water sales with crop share never existed since the emergence of the groundwater market.

2) Change in Profitability of Tubewells and Income Distribution

Table 6 summarizes results of cost and return analysis of tubewell operation, showing separately by deficit diesel STWs, surplus diesel STWs, electric STWs, and DTWs. Among the diesel STWs, 13 (65%) recorded financial deficit whereas the remaining 7 recorded surplus. It is really surprising to find that more than half of the STWs incurred a loss, if the situation in Village A in 1992 is remembered.

The drastic change in the situation can more clearly be observed in Figure 3, which shows the distribution of surplus, in relation to the achieved irrigated area (only for the STWs). Comparison with the case of Village A in 1992 (Figure 2) enables us to point out at least two facts. First, the fitted line shifted downwards, implying that the rate of return to STWs became much lower than before. Actually, the average rate of return became close to zero or even negative in 1999, a sharp contrast with the situation in Village A in 1992, where 69% of profit rate was obtained on average. Second, the profitability became more strongly correlated with command area, and it is about 9 acres that separates profit and loss, compared to about 5 acres in 1992.

It is plausible that the increase of tubewells in a confined area led to the reduction of command area on the one hand, and on the other hand, led to the decline of water price, and finally resulted that more than half of STWs fell into financial deficit. In other words, it seems that an over-investment in tubewells took place in the village on a large scale.

Table 7 showed the result of cost and return analysis of major crop production in Village C. Note here that the data was collected from tubewell owners, the majority of them are large farmers, and therefore involve some upper sample bias. However, it was found that the operators' surplus obtained from the estimates coincides more or less with the prevailing land rent in the village tenancy market.[13] It implies that the estimate was fairly reasonable and reliable.

Table 8 summarized the change of factor share in *boro* production during 1992-99. Income distribution experienced a drastic change during the short period.

First, the share to water in 1999 declined to only 13% (1,637 taka per acre). It was 31% (1,606 taka of cost plus 1,336 taka of profit) in 1992. The cost of irrigation did not change in nominal terms, which means that in real terms it declined substantially if inflation is taken into account. In addition, the high rate of profit accrued to tubewell owners in 1992 totally disappeared, which contributed to a substantial decline of real water price faced by water buyers.

Second, while the share to water decreased sharply, the share to land rose to a very high level. It increased from 22% to 49%, almost equal to that in the traditional crop-sharing system.

In sum, landowners now absorbed almost all the income decrease of water sellers. The benefit, therefore, from the increased competitiveness of groundwater market during the 1990s in Bangladesh was accrued to landowners, and not to the owners of other factors including labor and capital. The 'waterlords' disappeared from rural Bangladesh very quickly in a short period.

3) Irrational Farmers?

If it is true that the investment in tubewells continued to go beyond the point where the rate of return became zero or even negative, then what was the reason behind such a phenomenon? Can we say that such a behavior of (rich) farmers was irrational?

Before reaching to the conclusion, let us examine some issues. First, the possibility of over-estimated family labor cost in Table 6 needs to be examined, because family labor cost was estimated, based on answers of each respondent to the question how much if hired, although it

[13] The prevailing land rent for *boro* season (*potton*) in the village was 3,600-4,500 taka per acre, which was significantly lower than the operators' surplus of 6,353 taka generated from *boro* production. And even if the interest for working capital for cultivation is incorporated (because land rent was paid in advance), the rate rises to 4,320-5,400 taka per acre only, still lower than the surplus. However, according to interviews in the village, *potton* for *boro* season was at that time disappearing rapidly due to such a disequilibrium and instead of *potton*, the yearly tenancy called *sonpotton* (9,000-9,900 taka per acre) was expanding. Careful calculations for *sonpotton* revealed that under this system the loss of land rent in *boro* season can be fully compensated by the excess land rent paid in *aman* season. It is very plausible that the process of adjustment of land rent was happening through the change from *potton* to *sonpotton*.

seemed that the opportunity cost was low. However, even under the extreme assumption of zero family labor cost, it can save only about 2,400 taka on average.

Second, there is a possibility that if a farmer has his own tubewell he can utilize his land more intensively than before, and the benefit from it can compensate the deficit of tubewell operation itself. More concretely, intensive land utilization here means (1) the triple cropping (*aman*- potato/ mustard- *boro*) in a higher portion of land, and (2) the higher yield in the production of *boro* or potato/mustard.

Actually, it was revealed that the cropping intensity of tubewell owners' land was 231.4%, significantly higher than that of non-owner farmers' land (206.5%). Moreover, according to the group discussion and interviews carefully tried in a supplementary survey in September 2000, a difference in *boro* yield between tubewell owners and non-owners was observed, although the difference was no more than 2%.

Note here, however, that the effect of the increased cropping intensity is already incorporated in the calculation in Table 6. Nevertheless, since triple cropping became possible almost only when a farmer has his own tubewell, the operators' surplus generated from the additional cropping of potato or mustard should be added to the return to tubewell operation, which is estimated about 2,500 taka.[14] Moreover, if 2% difference in *boro* yield is converted into monetary terms, the additional revenue is about 800 taka. Thus combining 2,500 taka and 800 taka, the fitted line in Figure 3 should be shifted upwards by 3,300 taka.

Now, considering the above two points, let us try to shift the fitted line in Figure 3 upwards by 4,500 taka (assuming that the family labor cost is evaluated as one half of the estimates, 1,200 taka plus 3,300 taka). As shown in the figure, it is found that the profitability of tubewell investment improves to a substantial degree.

Moreover, there are transaction costs incurred by water purchasers such as the cost of negotiation (and monitoring) with water sellers concerning the timing and volume of water delivery, which cannot be easily evaluated in monetary terms.[15] Therefore, it may be concluded that if we consider such various benefits obtainable from holding their own tubewells, including non-monetary as well as monetary, the behavior of farmers who invested in STWs in the 1990s was not 'irrational', in a wider sense.

However, now we have to consider the reasons why there exist significant costs for farmers from non-holding of their own tubewells. And also why non-monetary transaction costs mentioned above happens in water sales in rural Bangladesh? These questions will be examined in the next section.

Finally, it should be added here that because of the existence of these costs, the investment behavior of farmers in STWs was 'rational', but the groundwater market itself fell into an inefficient situation from the social viewpoint. It goes without saying that rationality in economic behavior of individuals and inefficiency of the market can be fully compatible.

4) Why Trapped in 'Over-Investment' in Tubewells?

In order to investigate the above-mentioned issue, the location of tubewells was drawn in the *mauza* (revenue village) map (Map 2). Let us now try to examine the reasons why more than half of STWs fell into financial deficit.

Firstly, S1, S9, S10, S14, and S19 were the cases of new introduction of STWs in the command area of DTW1, which was installed in 1991. Except for S9, which was installed in 1985, others were installed after 1991; i.e. in 1994 for S14 and S19 and in 1998 for S1 and S10. It is plausible that because of the fact that the owner of DTW1 was discounting water charge to a substantial degree,[16]

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[14] The operators' surplus from production of potato/mustard (weighted average) was 3,333 taka per acre. And the average cropped area of *boro* by tubewell owners was 2.95 acres, 24.9% (the difference in cropping intensity between tubewell owners and non-owners) of which was devoted to the additional cropping of potato/mustard. Thus, we got about 2,500, by the calculation of 3,333_2.95_0.249.

[15] Dubash also emphasizes the same point by saying that "in addition to the economic costs imposed on the buyer by seller malfeasance, the buyer also bears costs in terms of time, discomfort, and prestige" and is explaining it more concretely by raising some examples (Dobash [2002], p.222).

[16] Whereas the water charge of diesel and electric STWs in the village was 1,800 taka and 1,500 taka per

the newcomers failed to secure enough command area and fell into financial deficit.

Secondly, S18 (installed in 1994) was located between the two early comers of DTW2 and S17, so that it failed to secure enough command area. It seems that S17 also fell into deficit due to the intrusion of S18.

Thirdly, S2, S3, S7, and S13 were the cases of competition with S21. Except for S13, other STWs were installed later than S21and failed to secure enough command areas.

Fourth, the case of SE1 (installed in 1994) deserves special attention. It seems that although it offered 17% lower water charge, it failed to deprive enough command areas from S15, because S15 was operated by a socially powerful *madrassa* (Islamic primary school) teacher, who started its operation in 1982, the first case of STW in the village.

In sum, generally speaking, the major reason why many STWs fell into financial deficit is that they intruded into the already well-established command area of other tubewells.

Then the question is why they intruded into the existing command area of other tubewells.

In response to such a question by the author, a typical answer was that they were frustrated because tubewell owners often failed to supply water 'properly', although the timing and volume of water is essential for crops. On the other hand, a typical comment by tubewell owners who heard such a complaint of water buyers was that water buyers were inclined to refuse the payment of the water charge whenever it was possible and it was sometimes really hard to collect it. "Under such circumstances, why should I supply water as they like?" said one of the DTW owners.

Another notable comment of the DTW owner was that, "Hey, can you see the STWs over there within the command area of my DTW? I am discounting water charge in a substantial degree but farmers who tried to install new STWs did appear. If not discounted, there must have been many more such farmers".

It should be noted here that these comments of both water buyers and sellers are a kind of 'extremes'. In the everyday transaction of water, they must actually be more cooperative and behave more friendly. However, at the same time, it can also be said that in rural Bangladesh the transaction cost in water sales is not negligible due to the behavior of both parties, rooted in distrust between the two.

The difference observed in the intensity of land use between tubewell owners and non-owner farmers, as reported earlier, can be attributable to the existence of such high transaction costs in a village community. As a result, even though individual farmers behaved rationally, groundwater market as a whole was trapped into inefficiency from the social point of view due to lack of enough coordination among villagers.

4. GROUNDWATER MARKET IN A WEST BENGAL VILLAGE

So far in this paper, the experience of the emergence and transformation of groundwater market in Bangladesh during the 1980s and 90s was presented. It is found by a field study in 2000 that almost the same story can also be found in West Bengal, India. This chapter reports the result of the survey, especially from a comparative viewpoint with the Bangladesh case.

The study village (Village D) was selected from Nadia district, which is known as one of the major agricultural areas where groundwater irrigation by private STWs rapidly developed since the 1980s. There is a town called Kalyani, 2-3 hours' distance north of Kolkata by either train or vehicle. And Village D is located about an hour's journey by vehicle northeast of Kalyani (Map 1). When preliminary survey was conducted in 1999, it had about 250 households in its territory of 360 hectares. The farmland was nearly 260 hectares, almost 100% of which was irrigated by tubewells. The major cropping pattern was double cropping of *aman* and *boro*, but horticultural crops such as vegetables and bananas were planted in a relatively elevated land.

1) Evolution of Groundwater Market

At the time of the survey in 2000, there were 2 state-operated DTWs and 31 private STWs in the village.

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acre respectively, DTW owners charged only 1,386 taka per acre, which was 8-23% lower than STWs.

The history of DTWs is quite long. They were constructed in April 1964. Both were electrified from the beginning and the water was distributed through a network of underground pipes. It means that the command area of DTWs has been technically fixed. The state government of West Bengal has directly operated the DTWs for more than 35 years. All the operation and maintenance costs have been born by the state and farmers only paid a highly subsidized water charge per acre basis. Although one operator and two assistants are officially nominated for each DTW and are fully paid, however, as they have been completely idle, the beneficiary farmers were obliged to employ one operator by themselves. For the task of problem-solving and necessary coordination, a beneficiary committee was organized, which is comprised of several key persons such as a local official of the minor irrigation department, chairman of *gram panchayat* office, operator, and a few representatives of beneficiary farmers. Approximately 20-25% of farmland in the village is covered by DTWs.

On the other hand, the STWs can be classified into three; i.e. diesel STW, electric STW, and submergible STW (hereinafter referred to as SM), the number of which in 2000 was respectively 3, 18, and 10. The SM is operated by electricity but the motor is buried under the ground below 60 feet. It is often called "mini-deep" because it exploits the groundwater below 180-200 feet, which is in the middle of 60-70 feet in case of STWs and 400 feet in case of DTWs. As Table 9 indicates, the distribution of tubewells, especially SMs, is highly skewed in favor of large farmers.

According to the information obtained from several elder intellectuals in the village, the process of the diffusion of STWs was as follows. First, diesel STWs were gradually diffused since the mid-1970s. Then they were converted to electric tubewells rapidly in the first half of the 1980s when a rural electrification program was launched in West Bengal. Many electric STWs were also newly installed at that time.[17] Thus by the beginning of the 1990s almost all the farmland in the village was irrigated by either DTWs or STWs. However, the groundwater level began to decline year by year and farmers were obliged to start converting the electric STWs into SMs. The conversion to SMs started for the first time in 1992 and its number increased rapidly thereafter, reaching 10 in 2000, but it was still going on at the time of the survey. The initial capital cost for the installment of SMs is more than 55,000 rupee, which is much higher than the ordinary STWs (less than 15,000 rupee).

Also according to several elder intellectuals in the village, the dominant contractual arrangement in groundwater market in the former period was the seasonal tenancy of land by tubewell owners with in-kind payment (3 *maund* of paddy per *bigha*), exactly the same system as *Chaunia* found in Village A, Bangladesh. However, since the mid-1980s water sales with cash payment increased gradually by replacing the seasonal tenancy, and at the time of the survey in 2000 only water sales were observed. Some of the tubewell owners told us that at present, even if they wish, farmers are not willing to rent-out land under seasonal tenancy. It seems that just as in the case of Bangladesh, the dominant mode of transaction in the groundwater market in West Bengal also experienced a drastic change from seasonal tenancy to water sales with cash payment. And in this process the real water price declined substantially due to the increased competitiveness of the market.

2) Analysis of Groundwater Market

The carefully collected financial data of STWs (including SMs) is shown in Figure 4, in relation to the achieved acreage. It indicates that most of the STWs except for some SMs incurred a loss, a more serious situation than the case of Village C, Bangladesh (Figure 3). There are several factors which brought about such a situation. First, there is an increasing competitiveness among tubewell owners, just the same as the case of Bangladesh, which reduced command area for each tubewell and also caused a decline of real water price. Second, the conversion from ordinary STWs to SMs started in 1992 brought about a sudden increase of irrigation capacity in the locality, since SMs can irrigate about three times as much land, compared to ordinary STWs. Therefore, when a STW is converted to a SM, it deprived command area from surrounding STWs and jeopardized the latter's sustained operation. The financial deficit of ordinary STWs can be regarded as a phenomenon in a transitional period when adjustment of the market is on-going. It is plausible that most of the ordinary STWs will gradually withdraw from the market.

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[17] Under the program called 'cluster' system, if 6 electric STWs were prepared for installation, priority was given for introducing electricity.

When such an adjustment is completed, can the owners of SM enjoy a high rate of return from the water sale business, deserved to be called 'waterlords' just as the STW owners in the 1980s? It is difficult to foresee the situation, but most probably, even if such a situation occurs it is temporary and competition among SM owners will finally erode it.[18]

Lastly, let us examine the income distribution issue. Table 10 summarized the result of cost and return analysis of *aman* and *boro* production in Village D, in comparison with the case Village C, Bangladesh. The data were collected from tubewell owners only and some upper sample bias is involved, but same as before, the fact that the estimated operators' surplus is almost equivalent with the prevailing land rent in the village indicates no serious problems in our data.

Only two points are discussed here from the table. First, in the case of irrigated *boro* production the share to water is 11%, slightly lower than the case of Bangladesh (13%). This is consistent with the fact that most of the tubewells in the village fell into financial deficit at the time of the survey.

Second, very interestingly, compared to the Bangladesh case, it is evident that the factor share to labor[19] is significantly larger at the sacrifice of other production factors, especially land. It may be said that the nature of agricultural and rural economic development in West Bengal was more egalitarian than in Bangladesh, although the reasons are not clear enough at this moment.[20]

5. CONCLUDING REMARKS

This paper discussed how the groundwater market emerged and was transformed during the 1980s and 90s in Bengal, based on several village case studies in Bogra district of Bangladesh and Nadia district of West Bengal, India. Finally, conclusions are briefly presented.

First, in the study areas of Bengal, private STWs diffused very rapidly during the 1980s, which contributed to the high agricultural growth rate and the progress of poverty reduction in rural areas. The major reason why tubewells diffused rapidly without progress of land consolidation projects was the emergence of groundwater market. Groundwater irrigation by tubewells covered almost all the farmland within a decade or so, by the beginning of the 1990s. At this initial stage, tubewell owners, most of them large farmers, rented land from non-owner farmers on a seasonal basis (land rent was paid in-kind after harvest), or sold water to them under the crop-sharing arrangement with water. Under these arrangements, the effective rate of water charge was very high, and tubewell owners enjoyed a high rate of return from their investment in STWs. The share to water in irrigated rice (*boro*) production reached as high as 30%, and accordingly the share to land decreased to slightly more than 20%, from 30-50% in the case of traditional rainy season rice (*aman*). It is difficult to deny the critical argument of the emergence of 'waterlords' in rural areas instead of the traditional landlords.

Second, however, what happened in the 1990s was the continuous new investment in STWs even though groundwater market had already 'saturated' by the beginning of the 90s. The number of STWs reached nearly or more than double during the next several years. This resulted in a rapid decrease of command area of tubewells (from 10-12 acres to 6-7 acres) and a substantial decline of real water price. The decline of water price occurred through changes in the dominant mode of transaction in the groundwater market, from seasonal tenancy and/or water sale with crop-share to

[18] Webster [1999] argued that tubewell owners exploit agricultural surplus as 'waterlords' in his study village in West Bengal, but he did not conduct any in-depth economic analysis. Our study shows a sharp contrast with his argument in the sense that many tubewell owners actually incurred a loss due to the fierce competition among them, which benefited water buyers.

[19] Cost of bullock and/or machineries for land preparation is included in the labor cost.

[20] The agricultural wage rate, if adjusted by market exchange rate between the two countries, is at most 35% higher in West Bengal than in Bangladesh. Still, it is far from sufficient to explain the difference in the factor share to labor. Therefore, tentatively we have to say that by some reasons or other the rice cultivation in West Bengal is more labor intensive than in Bangladesh. The finding of our study is consistent with Dasgupta [1998], who argued that compared to Bangladesh, 'growth with equity' was attained in rural West Bengal. However, his argument about the reasons behind it is not very persuasive. To explore the reasons, including the re-examination of the fact itself, is remaining as one of the major future research agenda.

water sale with cash payment. As a result, the rate of return to STW investment declined sharply. The share to water in irrigated rice production also decreased sharply to 11-13% from about 30% just several years ago. The 'waterlords', who once appeared in the 1980s, quickly left from rural Bengal by the end of the 90s.

Third, in 1999 or 2000 a sharp contrast was observed between Bangladesh and West Bengal in the factor share to land and labor in rice production. Namely, the share to land reached 50-58% in Bangladesh whereas it remained only 27-40% in West Bengal. The corresponding share to labor was 20-30% in Bangladesh compared to 38-42% in West Bengal. In other words, the decreased share of water in the case of irrigated rice production was almost totally absorbed by land in Bangladesh, while labor share remained at a very low level. However, to explore the reasons behind such a difference, including the re-examination of the fact itself, remains as a future research agenda.

Fourth, the analysis shows that many STWs fell into financial deficit in both regions in 1999 or 2000. However, it may not be able to say that individual farmers who additionally invested in STWs behaved 'irrationally', if various benefits from the ownership of tubewells, including non-monetary advantages, are taken into account. It is important to note that there is a significant differential in land productivity between tubewell owners and non-owner farmers. It was also suggested in the case of the West Bengal village that the groundwater market was not in equilibrium, where conversion to SMs from ordinary STWs was going on.

Fifth, the fact that individual farmers behave rationally does not necessarily means that the groundwater market is working efficiently. Rather, the groundwater market in Bengal can be evaluated as inefficient, due to the behavior of both water sellers and buyers. Water sellers are not conscious enough in delivering water to buyers in time and in proper volume, while water buyers have a strong tendency to refuse payment of water charges. Such a behavior in both parties strengthens each other, forming a vicious circle. Such a structure is the main cause of an observed significant differential in land productivity between tubewell owners and non-owner farmers, which induced socially excess investment in STWs.

Sixth, it should be pointed out that policy for the promotion of competition among tubewells through increased number of them in a confined area is effective to reduce water price and thus to improve rural income distribution, but at the same time, such a policy can easily bring about socially excess investment in tubewells, leading to a wasteful resource use, especially in the context of Bengal rural society.

Lastly, it should be noted in the case of the West Bengal village that the introduction of SMs is not a fundamental solution to the problem of declining water table. Market mechanism is not enough to solve the problem and it needs to be supplemented by some kind of community level coordination and government regulation. The above-mentioned problem of inefficient resource use arising from excess investment in tubewells is also difficult to solve by market mechanism only. The transfer of DTWs from the state government to farmer's groups now under progress in West Bengal also needs some non-market institutional mechanism. It is true that because of the market mechanism and the individual farmers' initiative groundwater irrigation (especially STWs) achieved a widespread and rapid progress and contributed to the rural economic development in Bengal since the 1980s. However, it is high time to re-evaluate the role of the government and the community in the minor irrigation sector.

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Table 1 Agrarian Structure of Village A (Bangladesh) in 1992

Land ownership (acre)	No. of Househ olds	Major Occupation of Household Head					Owned land (acre)	Opera ted land (acre)	No. of STWs
		Farmi ng	Agricultur al and other daily labor	Busine ss	Service (salaried job)	Other s			
0	102	18	68	6	1	9	0	28.6	0
0.01-0.49	34	15	9	4	0	6	7.2	16.7	2
0.50-0.99	14	8	4	0	0	2	9.7	21.4	2
1.00-2.49	25	18	1	1	2	3	34.2	40.5	4
2.50-4.99	17	13	0	0	3	1	56.8	62.2	8
5.00-	17	14	0	0	2	1	123.1	119.0	14
Total	209	86	82	11	8	22	231.0	288.4	30

Source: Prepared by the author.

Table 2 Irrigation Cost and Water Charge in Village A (Bangladesh) in 1992 (taka)

Operation & Maintenance cost	
fuel and lubricant oils	920
spare parts and repair	191
wages	128
Sub-total (c)	1,239
Depreciation cost of facilities	366
Total average cost (ac)	1,606
Water charge per acre (w)	3,210
w/c	2.59
w/ac	2.00

Note: The figures are per acre cost, an average of 30 STWs.

Source: Prepared by the author.

Table 3 Distribution of Net Irrigation Surplus in Village A (Bangladesh) in 1992

(taka)

_	"Landowners"	"Farmers"	STW owners	Total	Per acre
Land rent	265,446	150,750	218,507	634,703	2,064
Interest on working capital	_		_	_	_
for cultivation	0	41,772	139,064	180,836	588
for irrigation	0	3,927	65,238	69,165	225
Profit	0	2,052	408,710	410,762	1,336
Total	265,446	198,501	831,519	1,295,466	4,213
(Share %)	(20.5)	(15.3)	(64.2)	(100.0)	–

Source: Prepared by the author.

Figure 2 Profitability of STW Investment in Village A (Bangladesh) in 1992

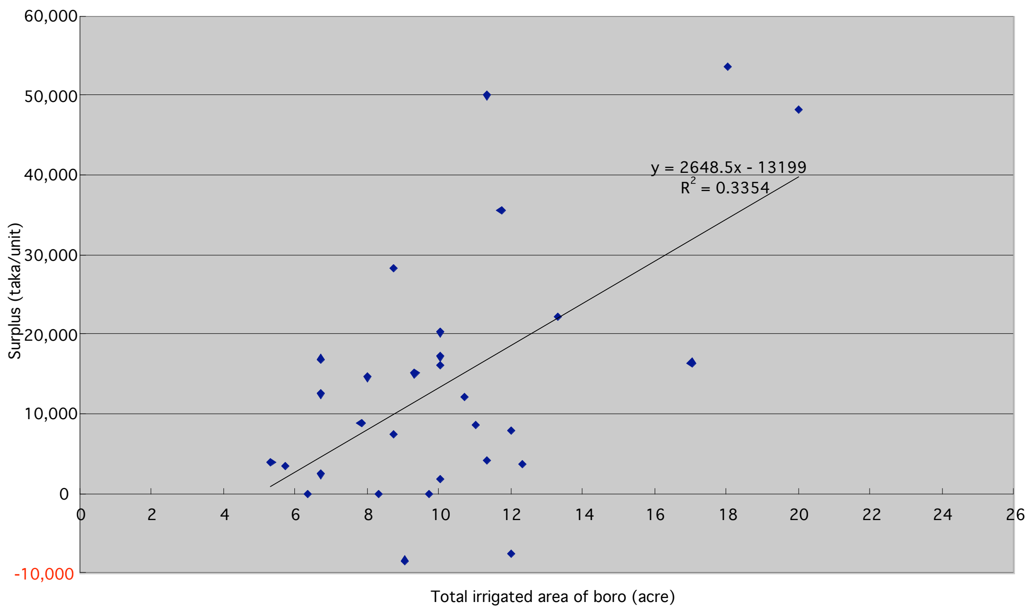


Table 4 Changes of Groundwater Market in Two Villages in Bogra, Bangladesh

_	Survey year	No. of STWs	Land irrigated (%)	Average irrigated area per STW (acre)	Yield of *boro* (*maund/bigha*)
Village A	1987_ 1999	38_ 80	94_ 100	12.0_ 6.1	10-11_ 12-15
Village B	1992_ 1999	30_ 52	90_ 100	10.3_ 6.6	13_ 16

Source: Prepared by the author.

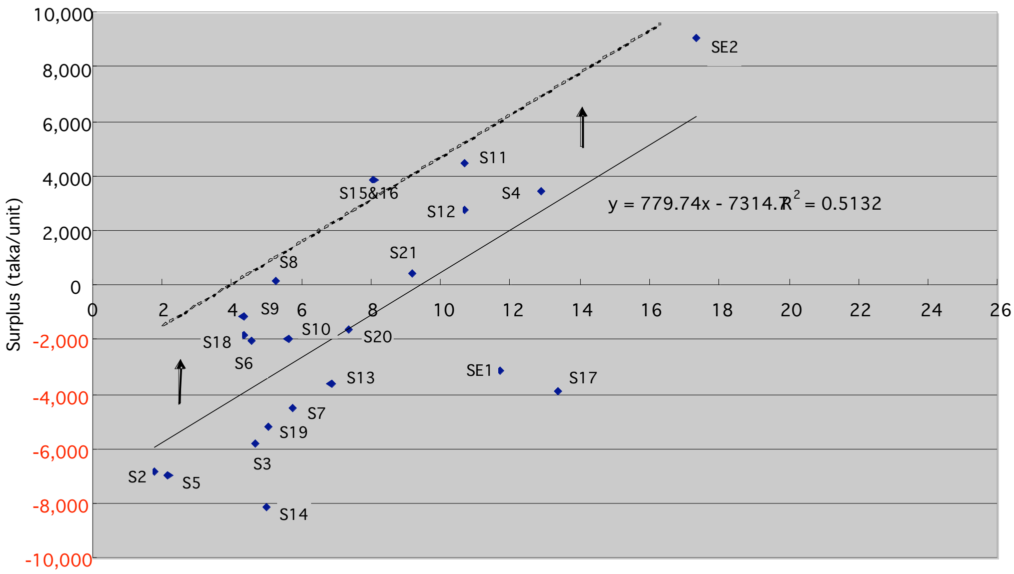
Table 5 Diffusion of Tubewells in Village C (Bangladesh)

_	Diesel STWs	Electric STWs	DTWs

	New	Replacement		
1982	1	_	_	_
1983	1	_	_	_
1984	1	_	_	_
1985	4	_	_	_
1986	_	2	_	_
1987	2	_	_	_
1988	_	2	_	_
1989	1	_	_	_
1990	1	2	_	_
1991	_	_	1	1
1992	1	1	_	1
1993	1	1	_	_
1994	4	1	1	_
1995	1	1	_	_
1996	_	2	_	_
1997	1	2	_	_
1998	2	2	_	_

Source: Prepared by the author.

Figure 3 Profitability of STW Investment in Village C (Bangladesh) in 1999



Total irrigated area in boro-unit (acres)

Table 6 Cost and Return of Tubewell Operation in Village C (Bangladesh) in 1999

	Diesel STWs		Electric STWs	DTWs
_	Deficit	Surplus		

No.of samples	13			7	2		2
Initial investment (taka)	14,027			14,757	23,750		214,000
Irrigated crop	Potato/ Mustard	*Boro*	Others	Potato/ Mustard	*Boro*	*Boro*	*Boro*
Total command area (acre)	23.1	65.4	2.0	14.2	56.8	29.0	115.5
Owned/Exchanged	9.9	22.6	0	6.4	14.1	5.7	3.0
Mortgaged-in	0.1	3.1	0	0	2.5	1.7	0
Rented-in	6.2	12.6	2.0	2.5	2.5	3.0	9.2
Water sales	6.9	27.1	0	5.3	37.7	18.6	103.3
Average command area per one tubewell	1.78	5.03	0.15	2.03	8.11	14.5	57.8
Water price (taka/acre)	390	1,776	360	626	1,801	1,500	1,386
Per Tubewell;	_	_	_	_	_	_	_
Total gross revenue (A)	9,683			15,884	21,750		80,042
Gross revenue from each crop	693	8,935	55	1,270	14,614	21,750	80,042
Cost	_	_	_	_	_	_	_
Diesel/Electricity	4,938			5,677	9,250		34,500
Lubricant oils	386			524	0		0
Spare parts/Repair	1,468			971	1,100		0
Tubewell house	632			464	1,000		2,400
Hired labor	2,235			3,143	5,625		12,000
Family labor (C)	2,792			1,647	0		0
Interest on working capital	623			621	849		2,445
Depreciation of facilities	706			646	792		6,420
Total (B)	13,780			13,693	18,616		57,765
Net revenue (A)-(B)	-4,097			2,191	3,134		22,277
Income (A)-(B)+(C)	-1,305			3,838	3,134		22,277

Source: prepared by the auther.

Table 7 Cost and Return of Crop Production in Village C (Bangladesh) in 1999

_	*Boro*		*Aman*		Potato		Mustard	
No. of samples	8		7		4		3	
Average cropped area (acre)	4.35		4.60		1.23		1.06	
Yield (ton/ha)	4.49		3.23		14.53		0.69	
Sales price (taka/*maund*)	250		269		121		633	
(Per acre)	taka	Share (%)	taka	Share (%)	taka	Share (%)	taka	Share (%)

Gross revenue	12,916	100	10,545	100	19,800	100	4,750	100
Paddy	12,147	_	9,366	_	_	_	_	_
Straw	769	_	1,179	_	_	_	_	_
Cost	6,564	51	4,454	42	13,958	70	3,743	79
Seed	288	2	183	2	3,855	19	168	4
Fertilizer	1,430	11	751	7	3,817	19	1,517	32
Chemicals	67	1	0	0	807	4	0	0
Irrigation	1,637	13	0	0	743	4	150	3
Rental of machineries	394	3	1,064	10	1,080	5	640	13
Labor (incl. family labor)	2,151	17	2,051	19	3,147	16	1,090	23
Interest on working capital	597	5	405	4	509	3	178	4
Surplus	6,352	49	6,091	58	5,842	30	1,007	21

Source: Prepared by the author.

Table 8 Changes of Factor Share in *Boro* Production in Bangladesh

	Village A in 1992		Village C in 1999	
_	taka/acre	Share (%)	taka/acre	Share (%)
Current inputs	1,411	15	1,785	14
Water charge	2,942	31	1,637	13
cost	1,606	17	_	_
profit of STW owners	1,336	14	_	_
Labor	1,987	22	2,545	20
Interest on working capital	813	9	597	5
Land rent (surplus)	2,064	22	6,352	49
Total	9,217	100	12,916	100

Source: Prepared by the author.

Table 9 Distribution of Tubewells in Village D (West Bengal) in 2000

Land ownership (acre)	Diesel STWs	Electric STWs	SM
0	-	-	-
0.01-1.49	-	-	-
1.50-2.49	1	3	-
2.50-4.99	2	2	3
5.00-9.99	-	6	3
10.00-	-	2	2
Cooperative	-	-	1
Total	3	13	9

Average farm size (acre)	2.72	6.54	7.00

Source: Prepared by the author.

Figure 4 Profitability of STW Investment in Village D (West Bengal) in 2000

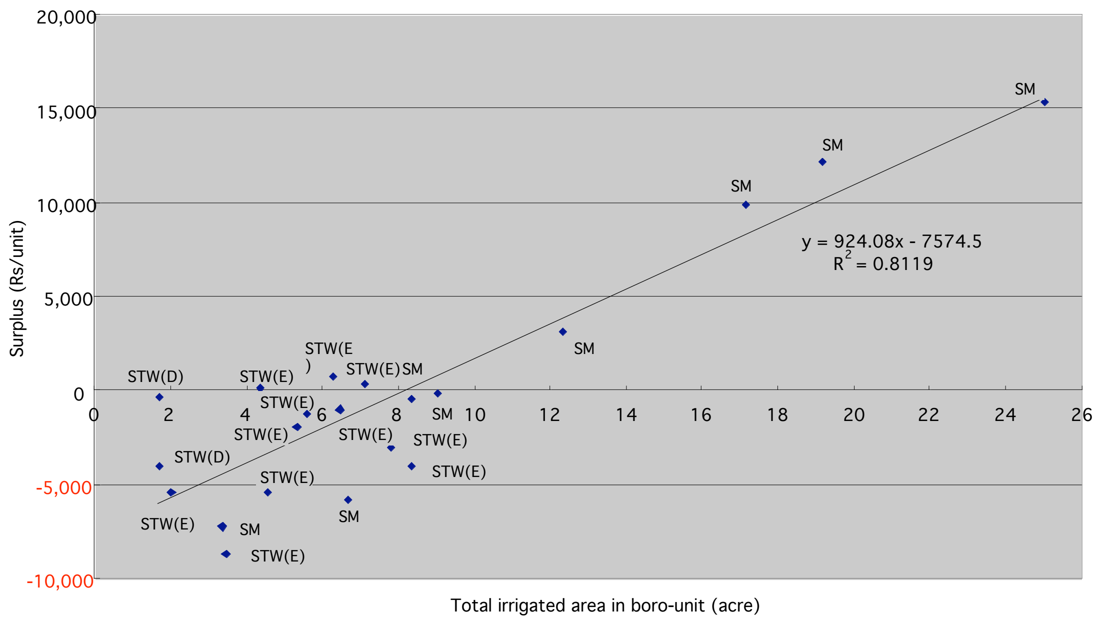


Table 10 Cost and Return of Rice Production in Bangladesh and West Bengal

	Aman				*Boro*			
_	Village C Bangladesh in 1999		Village D West Bengal in 2000		Village C Bangladesh in 1999		Village D West Bengal in 2000	
Sample size	7		9		8		11	
Yield (*maund/bigha*)	11.7		14.3		16.2		15.9	
(Per acre)	taka	Share (%)	Rs.	Share (%)	taka	Share (%)	Rs.	Share (%)
Gross revenue	10,545	100	9,690	100	12,916	100	10,890	100
Paddy	9,366	_	8,853	_	12,147	_	10,140	_
Straw	1179	_	837	_	769	_	750	_
Cost	_	_	_	_	_	_	_	_
Seed#	183	_	519	_	288	_	618	_
Fertilizer	751	_	783	_	1,430	_	1,878	_
Chemicals	0	_	204	_	67	_	207	_

Sub-total	934	8.9	1,506	15.5	1,785	13.8	2,703	24.8
–	–	–	–	–	–	–	–	–
Labor##	3,115	29.5	4,023	41.5	2,545	19.7	4,119	37.8
–	–	–	–	–	–	–	–	–
Irrigation	0	0.0	309	3.2	1,637	12.7	1,185	10.9
–	–	–	–	–	–	–	–	–
Interest on working capital	405	3.8	-	-	597	4.6	-	-
–	–	–	–	–	–	–	–	–
Total cost	4,454	42.2	5,838	60.2	6,564	50.8	8,007	73.5
Surplus (= land rent)	6,091	57.8	3,852	39.8	6,352	49.2	2,883	26.5

Note: # Cost of seedling in the case of Village D, West Bengal.

Including cost of bullock/machinery.

1 Rs= 1.21 taka.