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ROLE OF THE GROUNDWATER MARKET IN AGRICULTURAL DEVELOPMENT AND INCOME DISTRIBUTION: A CASE STUDY IN A NORTHWEST BANGLADESH VILLAGE

Kōichi FUJITA
Feroz HOSSAIN

I. INTRODUCTION

In the 1980s the wave of the Green Revolution finally reached to Bangladesh and the eastern part of India,[1] one of the most backward and poorest rice-producing areas in Asia. The engine of growth was the accelerated diffusion of tubewells (TWs). The exploitation of groundwater through the use of TWs converted the fallow land of the dry season into fertile paddy fields well suited to seed-fertilizer technology. This development in irrigated agriculture in Bangladesh can mainly be attributed to a series of policy reforms that started in the late 1970s, such as the privatization of irrigation equipment, the expansion of institutional credit in rural areas, and the de-standardization of TW engines.[2] Particularly the last reform, announced just after the devastating floods in 1987 and 1988, caused an influx of cheap engines from the Republic of Korea and China, contributing to the accelerated diffusion of shallow tubewells (STWs).

Since the launching of the privatization program, investment in TWs has been carried out in rural areas on an individual basis, especially by large-scale farmers. Given the overall small farm size and extreme fragmentation of plots, however, even an STW which has only four to five hectares of irrigation capacity can easily exceed the irrigation needs of its owner. Thus the sale of water to non-owner farmers has developed extensively, contributing to the expansion of irrigated areas. The

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1 The average annual growth rates of foodgrains (mainly rice) production in the 1980s were as follows: 3.2 per cent in Bangladesh (Fujita [4, p. 53]), 6.1 per cent in West Bengal, 3.4 per cent in Orissa, 3.1 per cent in Bihar, and 3.4 per cent in Uttar Pradesh (Sawant and Achuthan [12, p. A-6]).

2 For detail, see Fujita [4, Chap. 3].

efficiency and equity of irrigated agriculture depends largely on how well groundwater markets are working at the village level.

Using the primary data collected by the authors in a northwest Bangladesh village, this paper will evaluate the role of the groundwater markets in agricultural development and income distribution in rural areas.[3]

As we will discuss later in detail, various types of contractual arrangements for the transaction of water coexisted between TW owners and non-owner farmers in the study village. Various payment systems for the sale of water were found, such as the crop sharing system and the fixed cash payment system per acre. In addition to these systems, seasonal land tenancy by TW owners, locally called *chaunia*, was also observed on a large scale.[4] One of the major conclusions of this paper is that such a diversity in arrangements may be interpreted as an adaptation by farmers to the imperfect rural financial market. In other words, without the development of such diverse arrangements, poor farmers lacking capital could not have participated in irrigated agriculture.

The coexistence of various arrangements also made it possible to distinguish between land rent, interest on capital, and profit, and thus to clarify the whole structure of cost in irrigated rice production. The impact of the Green Revolution on rural income distribution could therefore be evaluated. It was found that compared with traditional rice farming carried on in the rainy season, the factor share of land decreased drastically while that of capital (interest and profit) increased. The factor share of labor did not experience any substantial change.

In Section II an analytical framework of groundwater markets is briefly presented. Then based on the primary data collected in the study village, Section III presents the empirical results and analyses. Lastly our conclusions are summarized in Section IV.

II. ANALYTICAL FRAMEWORK OF GROUNDWATER MARKETS

When a TW owner sells irrigation water to several farmers not owning TWs, how is the water charge determined?

The profit P which accrues to the TW owner during an irrigation season is defined as follows;

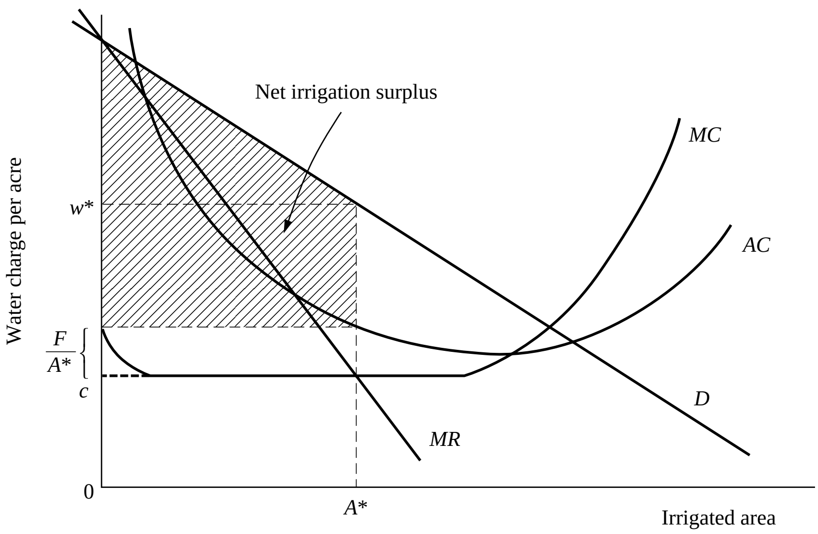
$$P = wA - cA - F,$$

where A is the acreage of the water sold (assuming that all the water is sold), w is

3 There has been relatively little economic research done on groundwater markets. See for example, Bangladesh Agricultural University [2][3] and Quasem [9] in Bangladesh; Shah [13], Pant [8], and Janakarajan [7] in India. But these research works only analyzed the ratio of w/c (w = water charge, c = variable cost of irrigation) or the internal rate of return (IRR) for TW investment. One of the advantages of this paper is that it also analyzes the distribution of net irrigation surplus among villagers which we believe is indispensable for an analysis of TW irrigation, because investment in TWs, unlike investment in large-scale canal irrigation, is weakly tied to farm land in the form of "land capital."

4 This type of seasonal tenancy has so far been reported only in a rather limited area of northwest Bangladesh, such as Rajshahi and Bogra. See Glaser [6] and Ando and Rashid [1].

Fig. 1. Determination of Water Charge and Net Irrigation Surplus



Source : Prepared by the authors.

the water charge per acre, c is the variable cost per acre for TW operation, and F is the fixed capital cost of a TW during an irrigation season.

Assuming the water seller holds a monopoly[5] and his behavior is to maximize profits, the equilibrium water charge w^* is obtained as follows;

$$w^* = e/(e - 1) \times c,$$

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

This relation is shown diametrically in Figure 1. Demand for water (D) is the derived demand from irrigated rice production by non-owner farmers. The marginal revenue curve for the TW owner (MR) is derived from D under the assumption of monopoly. At the intersection of the marginal cost curve (MC) and MR, the acreage of water sold A^* is determined along with the water charge w^*. Defining net irrigation surplus (NIS) as the surplus from which all the material and labor costs (including family labor cost imputed by the prevailing market wage rate) have been deducted from the gross revenue of rice production, NIS is equivalent to

[5] If the water charge demanded by a TW owner is unreasonably expensive, in theory the non-owner farmers are free to buy water from another TW owner, but in practice it is technically difficult except when land is located on the border between two TWs. However, the groundwater market is usually more or less competitive because competition among the TW owners is promoted by the existence of landowners in border areas. Moreover, non-owner farmers can sometimes buy and install TWs themselves, thus competition is further encouraged. The extent of monopoly depends on such factors as topographic conditions and the skewedness of capital resources among villagers.

the shadowed area in Figure 1. In theory it is composed of land rent, interest on capital, and profit. Shah [13] regarded the value of $e/(e-1)$ ($= w/c$) as a good indicator of the extent of monopoly held by TW owners in the groundwater markets.

III. GROUNDWATER MARKET: A CASE STUDY

A. *General Situation of Agriculture and Irrigation in the Study Village*

The study village is located on a diluvial plateau called the Barind tract in northwest Bangladesh and is free from regular floods. It had 209 households and 176 hectares of land at the time of the survey in 1992. The Barind tract has long been known as a single cropping area growing transplanted *aman*, a traditional rainy season rice, but the recent development of irrigation totally changed the situation. The rapid diffusion of STWs in the village during the 1980s (Table I) drastically changed its simple farming system to that dominated by the double cropping of *aman* and *boro* (a newly emerged irrigated rice) as shown in Table II.

Table III shows the skewed land distribution among villagers. Nearly half of the households are totally landless and 67 per cent of these are agricultural labor households. Off-farm employment opportunities are few. By contrast, the thirty-four largest landowners occupy nearly 80 per cent of the farm land, and it is these large landowners who own most (twenty-two out of thirty) of the STWs in the village.

B. *Transaction of Water among TW Owners and Non-Owners*

At the time of the survey in the summer of 1992, there were a total of thirty STWs owned by the villagers. Table IV shows the type of engine used for the TW, whether it is new or second-hand, and the irrigated acreage under various contractual arrangements. There were various types of engines: eight were new Japanese

TABLE I

NUMBER OF SHALLOW TUBEWELLS IN THE STUDY VILLAGE

Year	Newly Introduced	Total
1981	1	1
1982	0	1
1983	0	1
1984	3	4
1985	1	5
1986	0	5
1987	2	7
1988	3	10
1989	7	17
1990	6	23
1991	5	28
1992	2	30

Source: Prepared by the authors.

TABLE II

CROPPING SYSTEMS IN THE STUDY VILLAGE, 1991/92

Cropping Pattern	Acreage	% of Total
Aman—Boro	367	84
Aus—Aman—Khira	14	3
Aus—Aman—Boro	12	3
Aman	10	2
Others	33	8
Total	436	100

Source: Prepared by the authors.
Note: *Aus* = a paddy sown before the rainy season starts and harvested in the middle of the rainy season; *Khira* = a vegetable grown in the dry season.

TABLE III

SUMMARY OF AGRARIAN STRUCTURE IN THE STUDY VILLAGE

Land-ownership (Acres)	No. of HH	Main Occupation of HH Head (1992)					Owned Land (Acres)	Operated Land (Acres)	No. of STWs
		Agric.	Labor	Business	Serv.	Other			
0	102	18 (18)	68 (67)	6	1	9	0	28.6	0
0.01–0.49	34	15 (44)	9 (27)	4	—	6	7.2	16.7	2
0.50–0.99	14	8 (57)	4 (29)	—	—	2	9.7	21.4	2
1.00–2.49	25	18 (72)	1 (4)	1	2	3	34.2	40.5	4
2.50–4.99	17	13 (77)	—	—	3	1	56.8	62.2	8
5.00–	17	14 (82)	—	—	2	1	123.1	119.0	14
Total	209	86 (41)	82 (39)	11	8	22	231.0	288.4	30

Source: Prepared by the authors.
Notes: 1. Figures in parentheses show the percentages.
2. HH = households.

engines and fourteen were second-hand; and seven were new Korean or Chinese engines and one was second-hand. Six horsepower engines were used in all but one case. The irrigated area per TW varied from 5.3 to 20.0 acres, and averaged 10.3 acres.[6]

The contractual arrangements can be classified into three broad categories as follows.

The first is irrigation to the TW owner's own cultivated land. Land temporary exchanged between TW owners, though very small, is also included here. In all 35 per cent of the total land is irrigated under this arrangement.

The second is irrigation to land that TW owners cultivate seasonally as tenants;

6 The total irrigated area for all the TWs is about 307 acres which is quite different from the figure in Table II. In the study village there was a lot of irrigated land owned and operated by the farmers who live in the neighboring villages.

TABLE IV

ARRANGEMENTS FOR TRANSACTING WATER

No.[a]	Type of Engine[b]		New/ Old	Irrigated Area (Acres)					
				Total	Self-Operated	*Chaunia*	Water Sale		
							Crop Sharing	Cash + Crop Sharing	Cash
1	Yan	6HP	New	10.0	2.3	7.0		0.7	
2	Yan	6HP	New	18.0	1.3	9.7	7.0		
3	?	6HP	Old	9.3	5.0	2.3	2.0		
4	Mit	6HP	New	9.7	2.0	6.3			1.3[c]
5	Yan	6HP	Old	13.3	3.3	5.0	5.0		
6	Yan	6HP	Old	17.0	7.7	9.3			
7	Yan	6HP	New	6.7	5.0			1.7	
8	Yan	6HP	Old	11.0	4.3	4.3	2.3[d]		
9	Mit	6HP	New	12.0		11.3			0.7[e]
10	Yan	6HP	New	10.0	4.7	3.3		2.0	
11	Yan	6HP	Old	11.3	2.7	4.3		4.3	
12	Miy	6HP	New	5.7		2.0	3.7[d]		
13	Mit	6HP	Old	8.7	3.9	4.8			
14	Don	8.5HP	Old	10.0	8.3		1.7		
15	Yan	6HP	New	11.3	7.7		3.7[d]		
16	Miy	6HP	New	6.3	1.0	2.0		3.3	
17	Miy	6HP	New	6.7	1.0	2.0			3.7[f]
18	Miy	6HP	New	12.3	9.0			3.3	
19	Mit	6HP	Old	10.7	2.0	8.7			
20	Yan	6HP	New	20.0	4.7	6.0	9.3[d]		
21	Miy	6HP	New	12.0	4.7	6.3		1.0	
22	Yan	6HP	Old	8.7	3.3	4.7			0.7[f]
23	Yan	6HP	Old	8.0	5.0		3.0		
24	Don	6HP	New	10.0		8.0	2.0[d]		
25	?	6HP	Old	8.3	2.7	4.0			1.7[f]
26	Mit	6HP	Old	6.7	2.0		4.7		
27	Yan	6HP	Old	11.7	4.3	6.7		0.7	
28	Miy	6HP	New	9.0		7.0		2.0[g]	
29	Yan	6HP	Old	5.3	4.2			1.2	
30	Yan	6HP	Old	7.8	4.3	2.7		0.8	
Total				307.5	106.4	127.7	44.4	21.0	8.1
Average				10.3 (100%)	3.5 (35%)	4.3 (42%)	1.5 (14%)	0.7 (7%)	0.3 (3%)

Source: Prepared by the authors.

[a] In order from oldest to newest.

[b] Yan = Yammer (Japan), Mit = Mitsubishi (Japan), Miy = Miyanton (Korea), and Don = Donfing (China).

[c] Water charge is 2,250 taka per acre.

[d] Forty per cent share paid to TW owners (others are 33 per cent).

[e] Water charge is 2,400 taka per acre.

[f] Water charge is 2,100 taka per acre.

[g] Nine hundred taka per acre + 33 per cent share paid to TW owners (others are 300 taka per acre + 33 per cent).

this makes up the largest share of 42 per cent of the total irrigated land. Under this arrangement called *chaunia*, three *maund*s[7] (sometimes four *maund*s for the most fertile land) of paddy per one *bigha*[8] is paid as land rent to the landowners. The average yield per *bigha* in the village is about thirteen *maund*s.

The third arrangement is the sale of water itself; 24 per cent of the area is irrigated under this arrangement. The TW owners are responsible for the excavation of channels. The water is usually distributed by a rotation system. The water sale system is further subdivided into three systems in terms of the mode of payment; i.e., a crop sharing system, a fixed cash payment (per acre) system, and a mixed system of cash payment and crop sharing.

Under the crop sharing system, the share going to the TW owners is either 33 per cent or 40 per cent. Among the total of eleven cases, six paid 33 per cent and the remaining five paid 40 per cent. If we convert this into monetary term, payments ranged from 3,000 to 3,500 taka per acre. Under the fixed cash payment system, the rate ranged from 2,100 to 2,400 taka per acre, the major portion of which is paid in advance. Under the mixed system, a portion, usually 300 taka per acre, is paid in cash in advance and the remainder is paid as a share of the crop which is usually 33 per cent.

In summary, for farmers not owning TWs there are basically two options. One is to buy water from TW owners and operate the land themselves. The other is to rent out the land seasonally to TW owners and only receive a fixed amount of paddy as land rent. As we will discuss later, one of the most important determinants of which option a non-owner farmer chooses is how much working capital he can prepare before the start of the irrigation season.

C. *Economic Analysis of Water Charges*

It was found that 24 per cent of the irrigated land in the village was irrigated under water sale arrangements between TW owners and non-owner farmers. In this section we will make an economic analysis of the water charge, w, involved in this sale. Let us compare w with the variable cost of irrigation c, and also with the average cost of irrigation ac which is calculated by adding the depreciation cost (of TWs) to the variable cost c.

Table V summarizes the value of w, c, and ac for all the TWs for the 1991/92 irrigation season. For the crop sharing system and the mixed system, we estimated w by evaluating the amount of paddy paid to TW owners by its market price. The variable cost c is composed of such items as the cost of fuel and lubricating oil, the cost of repairs and necessary parts, and wage payments. Wages are paid to laborers hired for such work as excavating channels, operating TWs, and as night-guards to prevent theft. The depreciation cost of TWs is estimated by the constant amount method, assuming a life of ten years for new Japanese engines and five years for the others.

[7] One *maund* is equal to approximately 37.3 kg.
[8] One *bigha* is equal to one-third of an acre.

TABLE V

COST OF IRRIGATION AND WATER CHARGE

(Taka/acre)

No.	Variable Cost				Depreciation Cost	Total (ac)	Water Charge (w)	w/c	w/ac
	Fuel & Lubricating Oil	Repairs & Parts	Wages	Total (c)					
1	1,149	220	248	1,617	328	1,945	3,000	1.86	1.54
2	578	0	106	683	122	806	3,450	5.05	4.28
3	904	215	81	1,200	323	1,523	3,080	2.57	2.02
4	1,043	247	116	1,407	306	1,712	2,250	1.60	1.31
5	1,096	276	150	1,523	165	1,688	3,220	2.11	1.91
6	624	78	55	757	165	921			
7	1,209	200	313	1,722	224	1,946	3,900	2.26	2.00
8	1,032	259	145	1,436	273	1,709	3,312	2.31	1.94
9	989	565	131	1,685	125	1,810	2,400	1.42	1.33
10	950	252	225	1,427	280	1,707	3,450	2.42	2.02
11	714	33	0	747	345	1,092	4,620	6.18	4.23
12	1,119	142	118	1,380	807	2,187	3,240	2.35	1.48
13	622	78	54	754	276	1,029			
14	1,008	194	264	1,466	400	1,866	3,300	2.25	1.77
15	945	238	207	1,390	389	1,780	3,168	2.28	1.78
16	1,314	343	305	1,962	730	2,692	3,160	1.61	1.17
17	1,067	0	149	1,216	448	1,664	2,100	1.73	1.26
18	972	64	143	1,179	285	1,464	2,940	2.49	2.01
19	995	266	210	1,471	243	1,714			
20	776	225	67	1,067	140	1,207	3,864	3.62	3.20

TABLE V (Continued)

(Taka/acre)

No.	Variable Cost				Deprecia-tion Cost	Total (ac)	Water Charge (w)	w/c	w/ac
	Fuel & Lubricat-ing Oil	Repairs & Parts	Wages	Total (c)					
21	1,115	180	150	1,445	250	1,695	2,720	1.88	1.60
22	929	264	115	1,308	414	1,722	2,100	1.61	1.22
23	810	533	220	1,563	550	2,113	3,450	2.21	1.63
24	950	0	160	1,110	360	1,470	3,456	3.11	2.35
25	1,528	325	0	1,853	361	2,214	2,100	1.13	0.95
26	779	190	0	969	418	1,387	3,680	3.80	2.65
27	855	145	192	1,192	410	1,603	3,900	3.27	2.43
28	1,096	143	0	1,239	411	1,650	2,740	2.21	1.66
29	1,531	306	283	2,119	679	2,799	3,660	1.73	1.31
30	1,297	277	0	1,574	487	2,062	3,500	2.22	1.70
Average[a]	920	191	128	1,240	366	1,606	3,210	2.59	2.00

Source: Prepared by the authors.
[a] Weighted average in terms of irrigated area.

TABLE VI

Other Case Studies of the Water Market in Bangladesh

	No. of Samples	Average Irrigated Area (Acres)	Payment System (%)			Cost of Capital (Taka)	Per Acre		w/c
			Fixed Cash	Crop Sharing	Other		Variable Cost (c)	Water Charge (w)	
(1) STW	41	11.2	49	17	34	22,000	515	1,264	2.45
(2) LLP	61	37.8	82	—	18	31,250	390	667	1.71
(3) DTW	36	62							
Electricity	29	64	100	—	—	130,000	407	839	2.06
Diesel	7	54	—	100	—	130,000	807	1,680	2.08
(4) DTW	18	49							
Fixed cash	5	59	100	—	—	130,000	681	793	1.16
Crop sharing	13	45	—	100	—	130,000	861	2,122	2.46
STW	37	11.6	—	100	—	30,000	1,025	2,380	2.32
LLP	5	20.3	—	100	—	21,160	831	2,099	2.53
(5) DTW	26								
Fuel cost born by TW owners		63.3	100	—	—	130,000	795	980	1.23
Fuel cost born by farmers		45.6	100	—	—	130,000	288	459	1.59
LLP	17	32.4	82	—	18	28,750	433	728	1.68

Sources: For (1), M. A. Hamid et al., *Shallow Tubewells under IDA Credit in North West Bangladesh* (Rajshahi: Rajshahi University, 1982); for (2), idem, *Low Lift Pumps under IDA Credit in South East Bangladesh* (Rajshahi: Rajshahi University, 1984); for (3), W. M. H. Jaim and P. K. Shikhdar, "Privatization of Deep Tubewell—A Shift from Rental System: Who Gets Benefit?" mimeographed (n.d.); for (4), Bangladesh Agricultural University [2] (Tangail); and for (5), Bangladesh Agricultural University [2] (Dhaka).

Note: STW = shallow tubewells; DTW = deep tubewells; and LLP = low lift pumps.

The estimates of *w*/*c* and *w*/*ac* for each of the TWs is summarized in Table V. The value of *w*/*c* ranges from a minimum of 1.13 to a maximum of 6.18 and averages 2.59. TW No. 25, whose value of *w*/*ac* registered below unity, was the only one which incurred a financial deficit.

Comparing our estimates of *w*/*c* with some other case studies on Bangladesh, Table VI shows that the value of *w*/*c* in other studies ranges, on average, from 1.16 to 2.53, indicating that our study had a very high value of *w*/*c*. The situation does not change even when we compare it with case studies for India.[9] Nevertheless it seems too hasty to conclude from the above discussion that the groundwater markets in our study village is highly monopolistic. We need to proceed with an analysis of the distribution of net irrigation surplus among the villagers.

D. *Distribution of Net Irrigation Surplus*

Net irrigation surplus (NIS) has already been defined as the surplus from which all the material and labor costs have been deducted from the gross revenue of irrigated rice production. Irrigation costs (the sum of the variable cost *c* and the depreciation cost) are included in the material costs. There are large differences among the TWs not only in irrigation costs but also in gross revenue from rice production due to the differences in land quality. The result is wide differences in the NIS among the TWs. Moreover the distribution of NIS among TW owners, non-owner farmers, and other villagers also differs greatly. We estimated the value of NIS and its distribution for each of the TWs.

Table VII presents only the aggregated NIS and its distribution for all the TWs. The table shows that the total amount of NIS produced during the 1991/92 irrigation season in the study village was approximately 1.3 million taka, and its distribution was as follows: 20 per cent to landowners who seasonally rented out land to TW owners under the *chaunia* arrangement (hereafter referred to as "landowners"), 15 per cent to farmers who bought water from TW owners (hereafter referred to as "farmers"), and 64 per cent to TW owners. It should be noted that the distribution of landownership among the three categories of villagers was 42 per cent, 24 per cent, and 35 per cent, respectively.

Thus far we have estimated the distribution of NIS among villagers on a personal basis. However, considering that the distribution of NIS among production factors is more important for economic analysis, let us go on to this analysis.

First, the income going to "landowners" can be interpreted as land rent. Thus the rate of land rent is determined, which will be used in the following calculations. Second, the income going to "farmers" is interpreted as the sum of land rent and operator surplus. But after the imputed land rent was deducted from the income, still "surplus" of 650 taka per acre on average remained in the hands of "farmers," which is too large to regard as operator surplus. We concluded that the discrepancy

[9] According to Shah [13, p. 75], the value of *w*/*c* in India ranges from 1.2–1.3 in West Godavari to 2.7–3.0 in Panchmahal District of Gujarat, and 2.7–3.5 in Madurai District of Tamilnadu and Karimnagar District of Andhra Pradesh.

TABLE VII

DISTRIBUTION OF NET IRRIGATION SURPLUS

(Taka)

	"Landowners"	"Farmers"	TW Owners	Total	Per Acre
Land rent	265,446	150,750	218,807	634,703 (49)	2,064
Interest on cultivation capital	—	41,772	139,064	180,836 (14)	588
Interest on irrigation working capital	—	3,927	65,238	69,165 (5)	225
Profit (surplus)	—	2,052	408,710	410,762 (32)	1,336
Total	265,446 (20)	198,501 (15)	831,519 (64)	1,295,466 (100)	4,213

Source: Prepared by the authors.
Note: Figures in parentheses show the percentages.

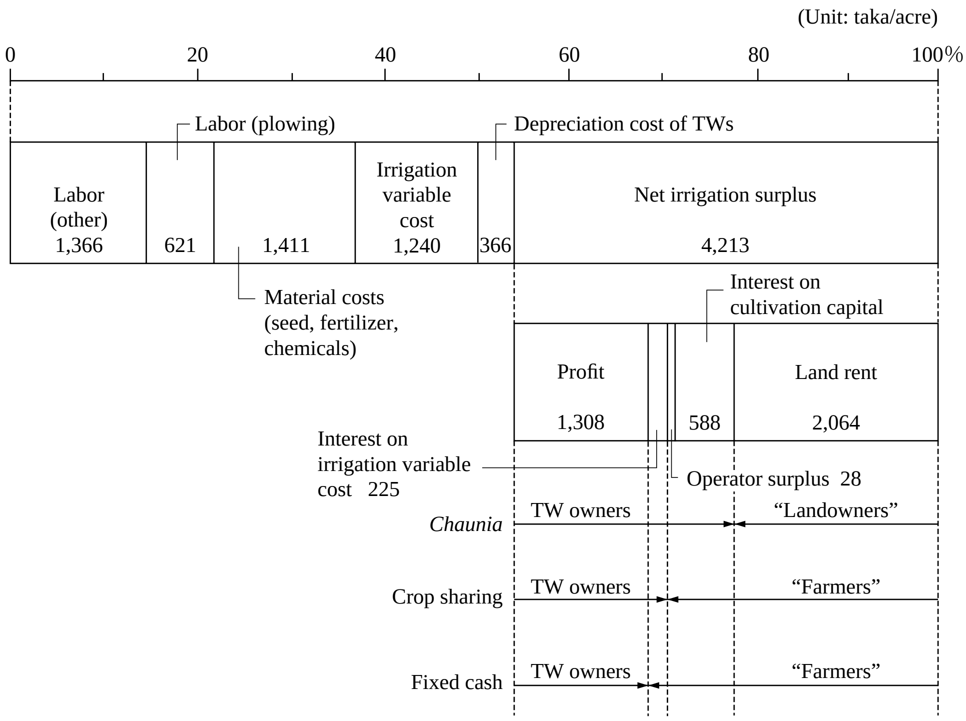
arose because we did not include the interest on capital in the production costs. We need to take into account the interest on the working capital for both cultivation and irrigation.[10] Considering that the short-term interest rate on the informal financial market in the village is more or less 100 per cent per annum, and assuming a two-month borrowing period on average,[11] the amount of interest can be estimated. When this estimated interest is deducted, the operator surplus becomes negligible as indicated in Table VII. By the same token, the income going to TW owners can be divided into land rent, interest, and profit.

We concluded that within the NIS produced in the village, the share of land was 49 per cent, the share of interest on working capital was 19 per cent (14 per cent on cultivation capital and 5 per cent on irrigation capital), and the share of profit was 32 per cent. It should be noted that most of the profit accruing to TW owners came as the return on TW investment, but a portion of this was distributed to "farmers" as operator surplus. Figure 2 summarizes the overall composition of factor shares in irrigated rice production. At the lower part of the figure, income distribution between TW owners and non-owner farmers under various contractual arrangements is presented. Under the *chaunia* system "landowners" get only land rent, and under the crop sharing system "farmers" get land rent and interest on cultivation working capital, while "farmers" under the fixed cash payment system get not only land rent and interest on cultivation capital, but also interest on irrigation (work-

10 The extent of risk sharing (such as fluctuations in crop yield and market price) differs greatly among the different arrangements. TW owners bear all the risks under the *chaunia* arrangement, while landowners bear all the risks under the fixed cash payment system. Under the crop sharing system, TW owners and landowners share the risks. In this context, the "surplus" remaining in the hands of "farmers" can also be interpreted as a risk premium. But in this paper, the "surplus" is interpreted as interest on capital.

11 The total production period for *boro* is about four months.

Fig. 2. Factor Share for Irrigated *Boro*



Source : Prepared by the authors.

ing) capital because they paid water charges in advance.[12] The implication is that the choice of arrangements for non-owner farmers depends upon the amount of working capital they can prepare before the start of the irrigation season.

Now we come to the point where we can discuss again whether the groundwater markets in the study village are monopolistic or not. The major point here is whether the profit accrued to the TW owners is reasonable or not. Table VIII summarizes for each of the TWs the profit obtained by the owners and the internal rate of return (IRR) calculated from it. The result is that the amount of profit on average is 13,624 taka and the average IRR is 69 per cent per annum.[13] The question is

12 Careful readers quickly see that the equilibrium water charge for the fixed cash payment system is 2,914 taka per acre (see Figure 2), which is quite different from the actual rate of 2,100–2,400 taka per acre. But this is because of the error of averaging. In fact, the quality of land under the fixed cash payment system is usually low, and so is the water charge rate. This can be confirmed by the operator surplus of TWs Nos. 4, 9, 17, 22, and 25 (in Table VIII) which accrues to the "farmers" under the fixed cash payment system and which in most cases is nearly zero.

13 The large differences in IRR among TWs are not attributed to the differences in the monopolistic power of TW owners. Rather, such factors as the managerial ability of TW owners and the quality of the land seem to be much more important in determining such large differences.

TABLE VIII

OPERATOR SURPLUS AND IRR OF STW INVESTMENT

No.	Operator Surplus (Taka/ Acre)	Profit of TW Owners (Taka)	Cost of Capital for TWs (Taka)	IRR (%)
1	–789	1,832	32,800	5.6
2	675	53,692	22,000	244.1
3	310	15,191	15,000	101.3
4	–599	128	29,644	0.4
5	593	22,367	11,000	203.3
6		16,575	14,000	118.4
7	152	12,599	15,000	84.0
8	–804	8,700	15,000	58.0
9	–41	8,059	15,000	53.7
10	177	17,303	28,000	61.8
11	1,504	50,120	19,500	257.0
12	692	3,535	23,000	15.4
13		7,547	12,000	62.9
14	938	20, 352	20,000	101.8
15	–1,192	4,198	44,000	9.5
16	–480	–28	23,000	–0.1
17	–460	2,527	15,000	16.8
18	–1,446	3,752	17,500	21.4
19		12,201	13,000	93.9
20	–187	48,388	28,000	172.8
21	–1,623	–7,447	15,000	–49.6
22	3,000	28,434	18,000	158.0
23	1,170	14,727	22,000	66.9
24	–299	16,222	18,000	90.1
25	138	44	15,000	0.3
26	1,208	17,033	14,000	121.7
27	1,331	35,680	24,000	148.7
28	–2,578	–8,291	18,500	–44.8
29	285	4,118	18,000	22.9
30	–143	8,877	19,000	46.7
Average	28	13,624	19,798	68.8

Source: Prepared by the authors.

whether the figure of 69 per cent is exorbitantly high or not.

In the study village there is a long-term land tenancy system locally called *khaikhalashi*, wherein an advance payment of 10,000–15,000 taka per acre makes it possible for the payer to secure cultivating right to the land for seven years. Considering that the annual expected land rent per acre is about 6,354 taka (as shown in Table X on p. 459), the yield of investment under this system can be estimated as 38–61 per cent per annum. The average IRR of 69 per cent on TW investment is thus a little bit higher than the long-term interest rate on the informal financial market. Also taking into consideration the risk involved in TW investment, it may be said that the profit accruing to the TW owners is more or less economically reasonable.[14]

To conclude, the income distribution in irrigated rice production cannot be regarded as unreasonable, if short-term and long-term interest rates in the village's informal financial market are taken into account. From this point of view, the groundwater market cannot be characterized as monopolistic, but rather it is competitive and efficient.

E. *Demand and Supply of Working Capital for TW Owners*

The development of the *chaunia* system in the study village has created the need for a substantial amount of working capital among the TW owners. Table IX shows the estimates of the capital needed by each of the TW owners during the 1991/92 irrigation season. According to the table, the amount ranged from a minimum of about 10,000 taka to a maximum of more than 110,000 taka, and the average was nearly 55,000 taka. Considering that the total amount of land rent for five acres of land is only about 30,000 taka, it is apparent that the need for working capital is burdensome even for large landowners.

Table IX also shows the actual amounts that the TW owners borrowed. A portion of the money borrowed under the *khaikhalashi* system is also used for irrigation (working) capital but has not been included in the figures. The table indicates that the average amount of borrowing is 7,600 taka which is only 14 per cent of the necessary capital. But it should be noted that there were seven TW owners who had to borrow more than 30 per cent of their needed capital. Furthermore, the rate of interest is most often very high. The interest rate at the commercial banks is about 16 per cent per annum, but few farmers can meet the requirements for access to this source. Most of the TW owners in the study village must rely on professional moneylenders who impose exorbitant interest rates of 100–120 per cent per annum and in some cases as high as 200 per cent. Most of the professional moneylenders live in a town several kilometers away from the village; some are Hindu moneylenders who have been active since the British era. Thus part of the NIS produced in the village is flowing out of the village in the form of capital interest.

F. *Bias of the Technological Change*

We will now estimate the factor share for transplanted *aman*, the traditional rainy season rice, and compare it with that of *boro*, the newly emerged irrigated rice. Through this analysis, we expect to be able to measure the technological bias of the Green Revolution. A point to be noted, however, is that in the study village which does not have regular floods, modern varieties now make up a significant part of transplanted *aman*. So strictly speaking, the comparison is not between before and after the introduction of Green Revolution technology, but between rainy season rainfed rice and dry season irrigated rice after the Green Revolution. It

[14] If the interest on working capital were not included in the production costs, the profit which accrues to TW owners would be much more; the average IRR would be 103 per cent per annum which can only be regarded as unreasonably high.

TABLE IX

REQUIRED WORKING CAPITAL AND CREDIT DEPENDENCY OF TW OWNERS

(Taka)

No.[a]	Variable Cost of Irrigation	Cultivation Costs		Total Working Capital	Amount of Borrowing	Credit Dependency Ratio (%)	Average Interest Rate[b] (%)
		Owned and Self-Operated	*Chaunia*				
1	15,955	7,590	23,100	46,645	0	0	
2	12,300	4,719	35,211	52,230	1,000	2	100
3	11,160	16,875	7,763	35,798	5,920	17	120
4	10,720	5,670	17,861	34,251	13,000	38	100
5	31,625	14,245	23,625	69,495	12,000	17	16
6	19,419	42,630	51,818	113,867	0	0	
7	11,030	19,875	0	30,905	0	0	
8	15,800	13,868	13,868	43,535	12,000	28	16
9	18,540	0	33,561	52,101	32,000	61	70
10	13,665	15,369	10,791	39,825	0	0	
11	17,065	23,805	35,745	76,615	32,000	42	48
12	7,865	0	6,150	14,015	2,000	14	100
13							
14	14,660	27,141	0	41,801	0	0	
15	15,710	26,565	0	42,275	0	0	
16							
17	380	3,240	6,480	10,100	7,000	69	100
18	13,515	34,425	0	47,940	0	0	
19	15,745	6,480	28,188	50,413	3,000	6	100
20	21,340	16,004	20,430	57,774	20,000	35	200

TABLE IX (Continued)

(Taka)

No.[a]	Variable Cost of Irrigation	Cultivation Costs		Total Working Capital	Amount of Borrowing	Credit Dependency Ratio (%)	Average Interest Rate[b] (%)
		Owned and Self-Operated	*Chaunia*				
21	17,040	16,920	22,680	56,640	20,000	35	0
22							
23	12,500	15,975	0	28,475	3,000	11	16
24	11,100	0	23,400	34,500	6,000	17	120
25	11,810	8,303	12,300	32,413	15,000	46	100
26	6,490	7,170	0	13,660	2,000	15	100
27	13,740	14,319	22,311	50,370	10,000	20	100
28	9,350	0	19,425	28,775	6,000	21	100
29	10,873	14,490	0	25,363	0	0	
30	12,040	15,158	9,518	36,715	4,500	12	100
Average	13,757	13,735	27,492	54,983	7,645	14	77

Source: Prepared by the authors.

[a] Statistics for TW No. 13 are included under TW No. 6 which is owed by the same person. Likewise TW Nos. 16 and 22 are included under TW Nos. 5 and 11, respectively.

[b] Weighted average in terms of amount of credit.

TABLE X

FACTOR SHARE OF RICE CULTIVATION

	Aman		*Boro*		Total	
	Taka/Acre	%	Taka/Acre	%	Taka/Acre	%
Material costs	939	11	1,411	15	2,350	13
Irrigation costs	300	3	1,606	17	1,906	11
Labor (plowing)	1,320	15	621	7	1,941	11
Labor (other)	960	11	1,366	15	2,326	13
Interest	587	7	813	9	1,400	8
Land rent	4,290	50	2,064	22	6,354	36
Profit (surplus)	184	2	1,336	14	1,520	9
Total	8,580	100	9,216	100	17,796	100

Sources: For *aman*, Rashid [11, p. 35]; for *boro*, prepared by the authors.

should be kept in mind, however, that the factor share of transplanted *aman* did not change substantially from before to after the dissemination of modern varieties.

Table X shows the factor share for both *aman* and *boro*. BR11 has been adopted for growing *aman* and is the most popular modern variety in the village. Interest on capital for material costs, labor costs, and irrigation variable costs were calculated at a rate of 100 per cent per annum for a two-month period, and incorporated in the *aman* production costs. *Aman* also requires supplementary irrigation especially at the primary stage, so farmers need to buy water from TW owners under the fixed cash payment system (300 taka per acre). Under the sharecropping tenancy system that is part of *aman* cultivation, the gross harvest is divided 50:50 with the landowners sharing none of the costs. Therefore we calculated the share of land as 50 per cent. The result was that a negligible operator surplus remained, indicating the appropriateness of our estimate.

One of the most remarkable facts pointed out by Table X is the large difference between *aman* and *boro* in the factor share of land. That for *aman* cultivation is 50 per cent while that for *boro* cultivation is only 22 per cent. At the same time, the factor share of capital (interest and profit) is more than 20 per cent for *boro* and less than 10 per cent for *aman*. The factor share of labor is more or less the same. It can be concluded that the new rice technology that expanded in Bangladesh mainly during the dry season as a result of the introduction of TWs, has had a strong land-saving and capital-using bias.[15] The implications of this finding are as follows.

First, the economic value of land, which has long been the basis for the dominance of large landowners in rural Bangladesh, has decreased drastically in the relative sense. At the same time the importance of capital has increased substantially. But this does not necessarily mean that rural income distribution worsened

15 The phenomenon of a drastic decline in the factor share of land in irrigated rice production could be observed in another village under our research project, which was located on a flood plain in Tangail District. According to our estimate, the factor share of land for *boro* was 21 per cent while that for *aman* was 50 per cent (Fujita [5]).

TABLE XI

FLOW OF CREDIT UNDER THE *KHAIKHALASHI* ARRANGEMENT

(Taka)

Landownership (Acres)	Amount of Lending	Amount of Borrowing	Balance
0	136,400	9,825	126,575
0.01–0.49	103,649	27,887	75,762
0.50–0.99	18,130	28,400	–10,100
1.00–2.49	45,450	73,300	–27,850
2.50–4.99	65,025	130,887	–65,862
5.00–	63,912	162,437	–98,525
Total	432,736	432,736	0

Source: Prepared by the authors.

after the Green Revolution. Rather at least potentially the opportunities for the landless and near-landless to climb the social ladder expanded greatly. In the study village, where most of the TW owners are at the same time large landowners and where land accumulation through seasonal tenancy by the TW owners has developed extensively, the landless and near-landless could not participate in the gains from the Green Revolution except for the increased employment opportunities and the wage hikes (though not substantial). But in other rural areas, especially where off-farm employment opportunities are more developed, we have observed many cases in which even the poor landless and near-landless have accumulated some capital and they have invested in the purchase of TWs or in usurious moneylending to TW owners.[16] Thus it can be said that such people have benefited from at least a portion of the increased factor share of capital.

Even in the study village where there were few off-farm job opportunities, the living standard of the landless and near-landless seems to have improved due to the rapid progress of double cropping. Induced by the increasing labor shortage at the peak period, a large number of migrants now come into the village from distant places. Because of this situation, even a reverse capital flow through the *khaikhalashi* arrangement can be observed (Table XI). It is clear that some of the landless and near-landless can save a large part of their annual wage income and invest it in *khaikhalashi* to secure cultivation rights to land for seven years.[17] The Green Revolution in Bangladesh has raised the value of capital vis-à-vis land, and this has not necessarily worsen rural income distribution, but rather the reverse phenomenon can often be observed.

A second implication concerns the land reform measures, especially the protec-

[16] In the same village as mentioned in the footnote 15, usurious moneylending to TW owners by poor landless and near-landless villagers was extensively observed (Fujita [5]).

[17] In the conventional view, *khaikhalashi* has been considered as a major route for small landowners to become indebted and finally landless (see, for example, Rahman [10, p. 166]). The reverse monetary flow from lower strata to upper strata in the study village sharply contradicts to this conventional view and is quite challenging (see also Fujita [5]).

tion of sharecroppers. The Tenancy Act of 1984 introduced the regulation of land rents for the first time in Bangladesh's history. The act states that in the cultivation of modern varieties, landowners can get half of the gross harvest if they incur half of the material costs, or one-third of the harvest if they do not share the costs at all. Under this regulation, the factor share of land is set more or less at 33 per cent. But according to Table X, the equilibrium for *aman* and *boro* is 50 per cent and 22 per cent, respectively. It is clear that in the case of *boro* the regulation does not protect but rather exploits the sharecroppers.

A third implication is the vulnerability of *boro* cultivation to price falls. A slight fall in the price of *boro* paddy can cause TW owners to stop water supplies which in turn can drastically reduce the area for growing *boro*. TW owners shut down TW operation when the paddy price falls beyond the point where they cannot make a profit and cover depreciation cost. From Figure 2, it can be seen that this point is at 1,674 taka per acre, which is about an 18 per cent of fall in price. It should be noted here that the land rent also decreases with a fall in the price of paddy, so the stoppage of water would be delayed to some extent. Nevertheless, irrigated *boro* cultivation is more vulnerable to price fall than is *aman* which is cultivated to a greater extent under rainfed conditions.[18]

IV. CONCLUDING REMARKS

This paper has used a case study of a northwest Bangladesh village to discuss the role of the groundwater markets in the development of irrigated agriculture and their impact on rural income distribution.

In the study village the influence of institutional credit is very limited and the interest rates on the prevailing informal financial market are very high; 38–61 per cent for long-term and 100–120 per cent for short-term credit. Small and marginal farmers are in particular restricted even to this informal financial market, especially for short-term credit from the professional moneylenders living in a nearby town. Meanwhile irrigated agriculture has developed rapidly with the introduction of TWs. However, this development is highly capital-intensive in nature, and it is difficult for the small and marginal farmers to participate in this newly emerged irrigated agriculture. In response to this difficulty, various arrangements for marketing of water evolved in the village, such as sharing the crop for water and the seasonal tenancy of TW owners. These contractual arrangements provided a means of giving credit to non-owner farmers and opened a way for their involvement in irrigated rice cultivation.

The water charge demanded by the TW owners in the study village was, on average, as high as 2.59 times the variable cost for TW operation, which was quite

[18] Actually the price of rice began to fall during the autumn of 1992, and for about a year it remained 30 per cent lower than the previous year. Many TW owners in the study village incurred huge losses during the 1992/93 irrigation season. Many villagers were worried that TW owners would stop the supply of water during the 1993/94 irrigation season. But the sudden recovery of rice prices at the end of 1993 prevented this worst case situation.

high compared with other case studies in Bangladesh. The groundwater market in the study village seems to be highly monopolistic. But when its function of giving credit to water buyers as stated above is taken into consideration, the conclusion is quite different because interest on working capital is included in the prevailing water charge. It was found that the return on TW irrigation was rather economically reasonable.

This is a case of an interlinking of factor markets, where the groundwater market and financial market are interlinked. The groundwater market itself is incomplete, in the sense that its development may seriously be constrained if small and marginal farmers are not provided with enough credit. Meanwhile the rural financial market is far from perfect and cannot fulfill the credit needs of farmers, especially small and marginal farmers. The contractual arrangements for the marketing of water in the study village can be seen as an adaptation to both of these incomplete factor markets. Thus it may be concluded that rural institutions, including the contractual arrangements in our case study, can play an important role in attaining efficiency and equity in an environment where markets are often either underdeveloped or imperfect.

Regarding the impact on factor shares in rice production, the factor share of land decreased significantly from about 50 per cent to 22 per cent while that of capital increased from less than 10 per cent to more than 20 per cent. The factor share of labor did not experience a substantial change. In sum, agriculture in the study village became more capitalistic with the introduction of Green Revolution technology. Such findings, however, do not necessarily mean that rural income distribution has worsened since the Green Revolution in Bangladesh, because at least a portion of the increased factor share of capital accrued to the lower strata villagers, especially in villages where off-farm employment opportunities are plentiful.

In the large-scale canal irrigation system managed by the government where the water rate is usually highly subsidized, the subsidy cannot be distinguished from land rent, which thus accrues to landowners. On the other hand, in the private TW irrigation system as analyzed in this paper, the division between returns on capital investment and land rent is rather clear. So the increased factor share of capital is not necessarily taken by landowners, but sometimes by villagers from the lower strata. This characteristics of TW irrigation can cause a reduction (rather than a widening) of income disparity in rural areas. But it depends largely on the structure of the local informal financial market, which would be an important future research topic to explore in other areas of Bangladesh and also in India where TW irrigation has rapidly expanded in the last decade.

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