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Determinants of Groundwater Price under Bilateral Bargaining with Multiple Modes of Contracts: A Case from Madhya Pradesh, India

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In response to a concern about irrigation owners' exploitative pricing to buyers, this paper investigates the determinants of groundwater price in Madhya Pradesh, India. Observing bilateral negotiations over groundwater prices between water sellers and buyers, we explicitly incorporate the differences in bargaining power as one of the determinants. Since the past literature on land tenancy markets suggests that prices become higher under output sharing contracts, we also examine whether this applies to groundwater markets. Our empirical analyses show that output sharing buyers pay higher prices to the sellers than buyers under either fixed or flat charge contracts presumably due to a risk premium payment and an implicit interest payment. Furthermore, we found that the water price becomes higher when the buyers have no alternative water seller nearby. Although these premiums attached to the water price may not be considered excessively high under the constraint of imperfect contingent markets, if equity is to be achieved, the individuals who must be targeted first are output sharing buyers who have no alternative sellers.

Key words: groundwater irrigation, bargaining, sharecrop contract.

1. Introduction

The absence of competitive markets in transaction of groundwater between owners of private irrigation systems and non-owners is widely observed in developing countries (Bagchi [1]; Campbell [2]; Dhawan [4]; Kahnert and Levine [10]; Pant [15]). Topography constrains the deliverable area of water when farmers use ditches and dikes. Capacity of water pump and length of conveyance facilities such as pipelines also limits the deliverable area. Therefore, the number of potential buyers that the owner of an irrigation system can expect is physically limited, as is the number of potential sellers that a non-owner can anticipate. Usually the owner and non-owner in close location become a pair of seller and buyer for water transactions, and the price is determined under bilateral bargaining between them. This implies that the price is not necessarily the competitive one. Moreover, there is a concern about the water sellers' exploitative pricing behaviors toward the buyers, which stems from conventional wisdom of treating the owners as "water-lords."

Past studies which use non-agricultural examples in developed countries give us some insight to answer this question (Chipty and Snyder [3]; Kauf [11]; Matulich, Mittelhammer, and Greenberg [12]; Oczkowski

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[14]). A common structure of their analytical framework is that a seller and a buyer bargain over the price such that the profit the seller (buyer) receives from the bargained price is no less than his reservation profit. The empirical results based on this framework show that price varies across pairs depending on the individual characteristics of sellers and buyers that determine their relative bargaining position and reservation profits.

A factor which makes such analysis unique in agrarian economies is the existence of different modes of contracts, especially output sharing contracts. Groundwater markets are no exception. In the land tenancy literature, it is often argued that the fee (land rent in case of tenancy) under output sharing contract becomes higher than other forms of contract. First, since output sharing contracts transfer production risk partially from buyers to sellers, a risk premium transfer could take place in the form of higher prices (Hayami and Otsuka [8]). In addition, since the output sharing buyers pay the water fee after the harvest, an implicit interest could be included in the water price. An empirical question thus arises: How are groundwater prices determined between the sellers and the buyers under bilateral bargaining with different modes of contracts?

Existing empirical analyses, however, have not answered this question completely. Many case studies estimate village level averages of the price-cost ratio to identify village level determinants such as depth of water table, rainfall pattern, energy source, and density of wells (Fujita and Hossain [7]; Shah [17]; Shah and Ballabh [18]). Several articles point out the effect of individual characteristics, although the statistical evidence is limited (Janakarajan [9]; Meinzen-Dick [13]; Pant [15]; Saleth [16]). Furthermore, the price under different modes of contracts has not been examined at the groundwater markets.

The objective of this paper is to explore the individual level determinants of groundwater price by taking into account the differences in bargaining positions and also in the modes of contracts. We conduct regression analyses using a newly available dataset from Madhya Pradesh in India, where private well irrigation systems have been proliferating. A notable advantage of this dataset is that it allows us to match water sellers and buyers so that we can include both parties' individual characteristics and then detect their relative bargaining position.

The following section compares groundwater markets in the study area with those discussed in past empirical studies. Section 3 presents variable construction and econometirc results. Finally, the main conclusion of this study and policy implications are provided in Section 4.

2. Characteristics of Groundwater Markets in the Study Area

1) Characteristics of the study area

A survey of groundwater irrigation management was conducted in 1998 in Madhya Pradesh, India. Among the villages with groundwater transactions, six villages located in two adjacent districts (Hoshangabard and Narshingpur) were randomly targeted. The villages are located in an area typified by deep-black soil and monsoon weather patterns. The main crops in the survey site are wheat and chickpeas during the dry season (*Rabi*), and soybeans during the rainy season (*Kharif*).[1] As the focus of our study was the use of groundwater irrigation, we confined our investigation to dry season agricultural activities. Key informants in each of the six villages provided data on village-level irrigation characteristics, summarized in Table 1. Our survey results indicate that the vast majority of farmers rely on groundwater to irrigate their crops. The prevalent means of extracting and distributing groundwater consist of private well systems comprising electric pumps, wells, and water conveyance facilities such as ditches and pipes. These farmers can be divided into three groups in terms of irrigation status: (1) well owners who do not sell surplus groundwater either because they are unwilling or unable to sell, the latter due to topographical and conveyance constraints, (2) well owners who sell surplus groundwater after completing irrigation of their own plots, and (3) buyers who do not own wells. In our study area the bargaining relationship between the latter two groups (i.e. sellers and buyers) is simple because the two groups are mutually exclusive; i.e., sellers do not purchase groundwater from other sellers.[2] Interviews with the village key informants also yielded information on the two groups of farmers essential for identifying

Table 1. Irrigation status of agricultural households in six villages

	Villages						
	A	B	C	D	E	F	Total
Number of agricultural households	70	106	93	100	101	90	560
Number of well owners (non sellers)	40	82	74	49	34	32	311
Number of well owners (water sellers)	3	9	7	8	8	6	41
Number of water buyers	4	9	12	15	27	12	79
Number of households irrigated by stream	3	0	0	18	8	12	41

matched pairs of sellers and buyers. Our survey indicates that buyers do not purchase groundwater from multiple sellers, whereas sellers provide groundwater to multiple buyers. Thus, the number of water buyers is greater than the number of water sellers in our study area.

The village-level interviews also reveal that three types of groundwater contracts exist in the survey area: fixed charge contracts (40%), flat charge contracts (22%), and output sharing contracts (38%).[3] As the name implies, fixed charge contracts entail a one-time fixed charge per season to irrigate a certain area. Flat charge contracts, on the other hand, require the buyer to pay a certain per-acre charge for each water application. Finally, under output sharing contracts, buyers pay for the water for a dry season crop by providing a certain ratio of their harvest after the growing period of that crop, ranging from one quarter to one third of the total harvest.[4] Although the provision of inputs is interlinked with land tenancy contracts in various parts of India, this situation was not observed in our study area: all the water buyers in the six villages surveyed cultivate individually-owned plots, thus eliminating the possibility of any contractual interlinkage between land and water provision.

2) Structure of groundwater markets in the study area

One of the simplest and most common methods of analyzing a market structure is to estimate the price-cost ratio. Table 2 shows the summary of past case studies and our study results. Based on their estimation result, Shah [17] and Shah and Ballabh [18] conclude that water markets in areas with high price-cost ratios are not competitive but monopolistic. On the other hand, even though Fujita and Hossain [7] obtain high price-cost ratios (2.59 for variable cost only or 2.00 for total cost), they deny sellers' monopolistic pricing because the rate of return to capital investment in irrigation systems (69%) is close to the interest rate in the informal financial market (38-61%). They conclude that if the risk of investment in irrigation systems is taken into consideration, the prices that the sellers charge may be economically reasonable.

We calculated the weighted average of price-cost ratios in our study area, obtaining relatively high ratios (3.18 and 1.98).[5] The rate of return to irrigation investment (24%) is above the annual interest rate of the credit program that farmers could use for irrigation installation (12-15%).[6] However, taking into account the risk factor as Fujita and Hossain [7] did, it appears that *on average* the water price in our study area is not excessively high, thus suggesting that the sellers' behavior may not be exploitative.

These results, however, do not necessarily support the existence of competitive markets (i.e. existence of one price) in our study area. Table 3 shows the results of OLS regression analysis of individual level input prices on village dummies for selected agricultural inputs. If a single competitive market exists in each village, we should not see large price variations after controlling for village level differences. Significant variations in fertilizer prices (urea, super-phosphate, and DAP) are ex-

Table 2. Ratios of water price to irrigation cost and returns to capital investment in different studies

Location	Ratio of water price to variable cost	Ratio of water price to the sum of variable and depreciation cost	Return to capital investment (%)
Shah [17] [a]:			
West Godavari, India	1.2 – 1.3		
West U.P. and Punjab, India	1.3 – 1.7		
East and Central U.P., India	1.7 – 2.0		
North Kheda, India	1.89		
Midnapur dist. West Bengal, India	2.3		
Panchmahal dist. Gujarat, India	2.7 – 3.0		
Madurai dist. T.N.; Karimanagar dist. A.P., India	2.7 – 3.5		
Shah and Ballabh [18] [a]:			
North Bihar, India	2.5 – 3.0	1.25 – 1.8	
Fujita and Hossain [7] [b]:			
Barind tract, Bangladesh	2.59	2.00	69 %
This Study [c]:			
Madhya Pradesh, India	3.18	1.98	24%

Note: [a] The basis for computing the ratio is Rs. per hour of pumping. [b] The basis for computing the ratio is Taka per irrigated acre. [c] The basis for computing the ratio is Rs. per acre. See Table A1 for detail.

plained by the village dummies (R-squared= 0.54 for urea, 0.72 for super-phosphate, 0.76 for DAP), implying that these input prices do not differ very much within the villages. On the contrary, the regression of groundwater prices shows that there remains a large amount of unexplained variation even after removing the village-level variation (R-squared=0.15). Thus, the structure of groundwater markets in our study area appears to be neither monopolistic nor competitive. Instead, it seems natural to conjecture that the groundwater price is individually determined between sellers and buyers; i.e., a bargaining structure prevails in the study area. Given this nature of groundwater markets, our empirical attempt is to identify the individual characteristics of sellers and buyers as well as village level factors that influence groundwater price formation. The individual characteristics must include not only agrarian and household characteristics but also the measures of bargaining powers and the contractual differences as the past literature on bargaining and agrarian contract respectively suggest to do so.

3. Empirical Analysis

1) Empirical approach and variable construction

In order to identify the determinants of groundwater price, we attempt to estimate a groundwater price function by OLS regressions. The dependent variable we use is the unit water price in wheat equivalent, defined as the ex-post total payment for water divided by the area irrigated and by the number of water applications.[7)]

The first set of explanatory variables is the bargaining power. The party with alternative transaction partners may be able to threaten the current partner by means of his possible withdrawal from the contract. In order to capture the seller's bargaining power, we construct a dummy which becomes one when alternative buyers exists for that seller. Likewise, the buyer's bargaining power is mea-

Table 3. Price variations within and across villages by types of input goods

	Dependent Variable			
	Urea price	Super phosphate price	DAP price	Unit water price
Village B dummy	0.208	0.250	0.083	-8.611
	(1.20)	(1.95)*	(0.30)	(0.98)
Village C dummy	-0.053	-0.100	-0.530	0.056
	(0.33)	(0.73)	(2.00)*	(0.01)
Village D dummy	-0.483	-0.250	-1.477	6.351
	(2.84)**	(1.89)*	(4.99)***	(0.73)
Village E dummy	-0.333	-0.033	-1.417	5.303
	(2.03)*	(0.27)	(4.14)***	(0.62)
Village F dummy	0.130	-0.167	-0.583	9.198
	(0.64)	(1.15)	(1.97)*	(0.97)
Constant	0.833	0.500	2.250	38.333
	(5.86)***	(4.22)***	(9.30)***	(5.24)**
Observations	38	26	28	50
R-squared	0.54	0.72	0.76	0.15

Numbers in parentheses are absolute *t*-values. * significant at 10% level; ** significant at 5% level, *** significant at 1% level.

sured by the dummy for the existence of alternative sellers in case of the rejection of the water supply from the current water seller. We also introduce a dummy variable to represent whether the seller and the buyer belong to the same caste.

Other important explanatory variables are the seller's and buyer's household characteristics related with agricultural activities. We use age for farming experience and schooling years for modern style farm management capability. The characteristics of the seller's irrigation technology may influence the price level. One of them is represented by the total investment in irrigation systems that consists of the costs of well digging, electric pumps, pipelines, and sprinkler systems. This variable attempts to measure the capacity of irrigation systems such as horsepower and water command area determined by the available conveyance facilities. Another is the sum of operational costs per acre which consists of the cost of electricity, costs of repairs and necessary parts, and wages for pump operations, if any. The inclusion of other inputs' prices may be suggested because they are linked with the demand for groundwater through substitution or complementation of inputs. Since significant variations in input prices are captured by the village dummies (Table 3), we use village dummies to control not only for village fixed effects but also for the differences in input prices.

Finally, we introduce two dummies of fixed and flat charge contracts in order to see whether prices are higher under output sharing contracts. The types of contracts, however, may be chosen simultaneously with the other endogenous variable, that is groundwater price. If this is the case, there are no extra exogenous variables which determine the types of contracts but do not appear in the groundwater price function (i.e. under-identified), and, thus, we have no way but to estimate the reduced form water price function without using dummies for the types of contracts. In this case, we cannot know how sharecropping is related with water price. On the other hand, we may claim that the parties make their decision stepwise: they first choose the types of contracts and then talk about how much the water price is. The types of contracts may persist for some period once a particular form is chosen in the past. Putting it another way, the rates may be flexibly adjusted under a particular type of contract, but the type of contract is not changed so flexibly once the buyers and sellers enter into it. If this is the case, the system becomes a recursive one at least in the short run, and then we can use the

Table 4. Summary statistics of variables for regression analysis

Variable	Mean	Standard deviation
Dependent Variable		
Unit water price (kg. of wheat)	40.3	15.0
Explanatory Variables		
Contractual Status		
Fixed charge dummy [a]	0.40	
Flat charge dummy [a]	0.22	
Bargaining Power		
Existence of alternative buyers dummy	0.64	
Existence of alternative sellers dummy	0.44	
Caste matching dummy	0.40	
Seller's Household Characteristics		
Seller's age	47.2	14.5
Seller's schooling years	4.10	4.01
Buyer's Household Characteristics		
Buyer's age	45.3	11.8
Buyer's schooling years	6.06	5.27
Characteristics of Irrigation Systems		
Total amount of investment to irrigation (1000 kg. of wheat)	6.85	5.49
Sum of operational costs (kg. of wheat)	46.0	38.2
Controlling Variables		
Village B dummy	0.18	
Village C dummy	0.20	
Village D dummy	0.20	
Village E dummy	0.22	
Village F dummy	0.12	

[a] Numbers shown are proportions of samples under different contracts.

sharecrop dummy as a predetermined exogenous variable in our water price function. Nevertheless, we can never deny the simultaneity of their decision process, so that we run regressions with the dummies to compare with the models without the dummies. The descriptive statistics of the variables are summarized in Table 4.

2) Regression results

The regression results are reported in Table 5. The results of Model 1 show that two dummies are both negative and significant.[8] The null hypothesis that the coefficients of fixed charge and flat charge dummies have the same magnitude is not rejected by the *F* test (see the lower portion of the table), implying that the difference between these two types of contract is not observed at least in the difference in price levels. Hence, they are combined to create a new dummy variable named nonshare dummy, and the results are reported as Model 2. Model 2 indicates that the water buyers under output sharing contracts pay higher water prices by about 14 kg of wheat to the sellers than those buying under the other forms of contracts.

What are the reasons for the higher prices? The theoretical model on agrarian contract attributes the higher groundwater price for output sharing buyers to the existence of a risk premium payment from the buyers to the sellers (Hayami and Otsuka [8]). Another reason may exist; the water prices become higher for sharing buyers presumably because an

Table 5. Regression analysis of the determinants of water price

	Model 1	Model 2	Model 3
Contractual Status			
Fixed charge dummy	-13.152		
	(1.91)*		
Flat charge dummy	-16.135		
	(2.14)**		
Non-share dummy		-14.282	
		(2.24)**	
Bargaining Power			
Alternative buyers	1.457	1.303	4.141
	(0.29)	(0.27)	(0.83)
Alternative sellers	-10.370	-10.712	-10.794
	(1.83)*	(1.93)*	(1.84)*
Caste matching	5.454	5.096	6.844
	(1.15)	(1.10)	(1.42)
Seller's Household Characteristics			
Age	0.163	0.141	0.177
	(0.92)	(0.84)	(0.99)
Schooling years	1.585	1.565	1.700
	(2.26)**	(2.27)**	(2.34)**
Buyer's Household Characteristics			
Age	-0.103	-0.107	-0.135
	(0.54)	(0.56)	(0.67)
Schooling years	0.473	0.405	0.132
	(0.86)	(0.77)	(0.24)
Characteristics of Irrigation			
Total amount of investment	-0.042	0.075	0.092
	(0.07)	(0.15)	(0.17)
Sum of operational costs	-0.049	-0.055	-0.051
	(0.80)	(0.93)	(0.81)
Controlling Variables			
Village B dummy	10.524	10.605	7.590
	(0.94)	(0.96)	(0.66)
Village C dummy	17.475	18.386	19.957
	(1.59)	(1.72)	(1.77)
Village D dummy	9.667	9.467	13.781
	(1.02)	(1.10)	(1.42)
Village E dummy	-9.423	-8.911	2.946
	(0.84)	(0.80)	(0.29)
Village F dummy	22.248	22.040	18.108
	(2.04)**	(2.05)**	(1.62)
Constant	32.856	34.179	20.437
	(2.05)**	(2.20)**	(1.35)
F test	0.23		
(Null hypothesis: the coefficients of contractual dummies are equal.)	[0.63]		
Observations	50	50	50
R-squared	0.45	0.45	0.37

Numbers in parentheses are absolute *t*-values. Numbers in brackets are *p*-values. *significant at 10% level; **significant at 5% level.

implicit interest payment is included to compensate sellers for the post-harvest payment in arrears. Assuming these two are the reasons for higher prices, is the price differential paid by output sharing buyers excessively high? The regression results indicate that this difference amounts to about 14 kg of wheat per unit of water. Since the mean water price of non-output-sharing buyers is 36 kg of wheat, the implicit premium rate shouldered by the output sharing buyers is approximately 39% for 6 months of dry season. In our study area, in most cases, the informal interest rate for farming purposes is 5% per month which is equivalent to 34% for a season.[9] If the price differential consists not only of the implicit interest of 34% but also of some percentage of risk premium, the implicit premium rate of 39% shouldered by output sharing buyers may not be considered as unreasonable in the circumstances given the imperfection of both credit and insurance markets in rural areas.

The results in Model 3, which does not include the contractual dummies, show that a few coefficients change their values across the models, indicating that we cannot completely exclude the possibility of simultaneous decision making regarding contract choice and groundwater price. However, obtaining highly significant results in Models 1 and 2, we still had better pay our attention to the possibility of the transfer of profit from the output sharing buyers to the sellers.

Since the magnitude of the coefficients does not vary across the models for the coefficients which are significant, the interpretations shown below regarding the rest of the significant variables are robust across the models. One of notable results besides the impact of share contract is that the seller's bargaining power (dummy of alternative buyers) has no statistical effect on price, whereas the buyer's (dummy of alternative sellers) significantly reduces the water price. The insignificance of the seller's bargaining dummy can be explained by the impotence of his threat: buyers realize that sellers want to sell water to as many buyers as possible once the sellers' irrigation systems become idle after finishing irrigation of sellers' own plots and thus do not believe the sellers' threat of withdrawal from the transaction. On the contrary, the buyers' threat is more compelling. This is because buyers usually buy water from only one seller for a plot. Therefore, the implication of switching to a different seller would threaten the current seller. In other words, if the buyer has alternative sellers, he can bargain over price. Fujita [6] found from his re-survey of the selected villages in Fujita and Hossain [7] that the increase of the number of tube wells had significantly reduced the groundwater price, which is consistent with our regression results.

The coefficient of seller's education is significant. Two possible explanations may be posited. The first is that the value of advice on irrigation from the seller is reflected in the water price.[10] The second is that the seller's educational level may capture his social status associated with some bargaining power. Nevertheless, as the impact of education is relatively small (1.6-1.7 kg for one more year of schooling), equity at groundwater markets is unlikely to be greatly affected by the sellers' educational status.

Regarding irrigation technology variables the coefficient of total investment is not significant, implying that groundwater price does not differ between expensive (i.e. effective) and less expensive (i.e. less effective) irrigation systems. The coefficient of the sum of operational costs is not significant either. Since fixed electricity costs and repair costs, which comprise the largest part of operational costs, have to be incurred by the seller regardless of the amount of groundwater used by the buyer, the marginal cost is close to nil, resulting in the insignificant coefficient.[11] In this regard, the groundwater price in our study area is set not mainly with the intention of covering the explicit costs but of charging an implicit risk premium and interest payment to sharing buyers and also of enjoying some bargaining premium from the buyers who have no alternative seller.

4. Concluding Remarks and Policy Implications

This paper analyzed the determinants of groundwater price using a sample of water sellers and buyers in six irrigated villages in Madhya Pradesh, India. The large variations in price for the same irrigation water indicates that price is individually negotiated between sellers and buyers in groundwater markets where only a limited number of buyers and sellers can enter the transaction due to the limitation of the command area. The examination of village or larger level averages in the past literature may, therefore, ignore important individual characteristics inherent in high groundwater prices. The results of our regression analyses show that buyers under output sharing contracts pay approximately 34% higher prices to the sellers than buyers under either fixed or flat charge contracts presumably due to a risk premium payment and an implicit interest payment, although the potential endogenous problems is ignored. Furthermore, in groundwater markets, we found that the water prices become higher when no alternative water seller is located nearby.

Given the interest rates in informal rural credit markets, the premiums from buyers to sellers may be considered as not being excessively high. However, if we have to target policies for the achievement of equity in groundwater markets for political reasons, the individuals who must be targeted first are the output sharing buyers who have no alternative seller. This implication would not be revealed from the analyses of village level averages. One of the policy options for such buyers may be the provision of credits at favorable interest rates for the acquisition of their own irrigation systems. However, it may be difficult to correctly distinguish such buyers from other buyers in a process of application selection. Even if it is possible, it may be difficult to justify why only some particular buyers are given a support and the other buyers are not. More practical policy options for such buyers may be designed from two different angles: those dealing with buyers having no alternative sellers and those dealing with output sharing buyers. For the first group of buyers, giving subsidies for the purchase of water conveyance facilities would increase their chance to obtain access to alternative sellers and thus reduce the water price. Creating public or semi-public shops from where farmers can rent conveyance facilities at a favorable rate would also work in the same way. Since the buyers with no alternative sellers would most enjoy the benefits from such a policy and the others would not, we could reduce the possibility of over dissemination of subsidies through such a self-targeting mechanism.

For the second group of buyers (i.e. output sharing buyers), designing policies with a self-targeting mechanism may be difficult. Nevertheless, policies from which the output sharing buyers would benefit most may be those that reduce the production risk and the risk from output price fluctuations because such policies would help eliminate the risk premium payment or even the sharing contract itself. The premium transfer would also be reduced if credit and insurance markets are more developed. Future projects would entail research on the livelihood of the output sharing buyers who have no alternative sellers that would help policy makers design more detailed policy options.

1) Sugarcane is cultivated throughout the year but it is a minor activity in the study villages.
2) According to Shah [17], in other areas of India, the owners who have multiple plots at different places sometimes buy water from other owners who have wells nearby.
3) Besides these three types of contracts, Shah [17] observes several different types in Andra Pradesh in India. First is the labor contract under which a buyer provides labor and draft power to his seller in return for water. Second is the crop and input sharing contract under which a seller provides water, and shares the buyer's input costs and harvest (interlinked contract). Fujita and Hossain [7] observe a contract called *"chaunia"* in Bangladesh under which a well-owner rents land during the dry season from a landlord who does not own irrigation systems. We observe no such contracts as those observed by Shah; there is only one case in our dataset which resembles a *"chaunia"* contract.
4) The share in other regions varies from one third in Andra Pradesh and Tamil Nadu to one half to two thirds in Gujarat (Saleth [16]).
5) See Table A1 for the detail.
6) Interest rates in the informal credit market for short term lending vary from 3% to 5% per month which are equivalent to 43% to 80% per year in our study area. These credit sources are usually used for relief from short-term liquidity constraints such as weddings, medical treatment, and the purchase of modern agricultural inputs rather than for long-term investments.
7) As is the case in our study area, water rates on an acreage basis are prevalent when farmers use electric pumps with free or fixed power cost. In areas where farmers use diesel pumps or electric pumps with per hour power cost, hourly bases are commonly used (Saleth [16]; Shah [17]).
8) One may be concerned that the output sharing buyers' payments became high simply because the

Table A1. The water-price-cost ratio and the rate of return to irrigation investment

Sample	(1) Water price/acre (Rs.)	(2) Operational cost/acre (Rs.) [a]	(3) Capital investment/ acre (Rs.) [b]	(4) Area irrigated by buyer (acre)	(5) Ratio of water price to operational cost [c]	(6) Ratio of water price to the sum of operational and depreciation costs [d]	(7) Capital return (%) [e]
1	133	253	2111	3.0	0.53	0.37	-5.68
2	180	188	2412	2.5	0.96	0.58	-0.31
3	200	398	6154	3.5	0.50	0.28	-3.22
4	200	909	2800	8.0	0.22	0.19	-25.31
5	200	238	5780	2.0	0.84	0.38	-0.65
6	300	324	1364	2.0	0.93	0.76	-1.77
7	300	352	7333	2.0	0.85	0.42	-0.71
8	333	733	6000	1.5	0.45	0.32	-6.67
9	360	387	2500	5.0	0.93	0.70	-1.07
10	375	380	2545	3.0	0.99	0.74	-0.20
11	375	140	2800	2.0	2.68	1.34	8.39
12	375	300	800	4.0	1.25	1.10	9.38
13	400	50	700	1.0	8.00	4.71	50.00
14	400	324	1364	0.8	1.23	1.02	5.56
15	450	138	4500	2.0	3.27	1.24	6.94
16	480	521	3118	2.5	0.92	0.71	-1.33
17	500	589	1500	2.0	0.85	0.75	-5.93
18	500	311	4000	1.0	1.61	0.98	4.73
19	500	363	4267	2.5	1.38	0.87	3.20
20	500	92	3200	2.5	5.43	1.98	12.75
21	600	311	4000	1.0	1.93	1.17	7.23
22	600	343	1333	3.0	1.75	1.47	19.29
23	600	352	7333	3.0	1.70	0.83	3.38
24	625	672	2023	0.4	0.93	0.81	-2.35
25	750	725	3200	1.0	1.03	0.85	0.78
26	750	672	2023	0.5	1.12	0.97	3.83
27	800	311	4000	0.5	2.57	1.57	12.23
28	900	107	5333	2.0	8.44	2.41	14.88
29	900	471	1600	3.0	1.91	1.63	26.79
30	1000	267	667	5.0	3.75	3.33	109.95
31	1000	766	9600	0.5	1.31	0.80	2.44
32	1000	343	1333	3.0	2.92	2.44	49.30
33	1042	166	1882	6.0	6.27	4.00	46.53
34	1067	226	8571	1.5	4.71	1.63	9.81
35	1067	226	8571	1.5	4.71	1.63	9.81
36	1083	188	2412	1.5	5.78	3.52	37.14
37	1167	107	5333	1.5	10.94	3.13	19.88
38	1200	1167	2231	3.0	1.03	0.94	1.48
39	1250	902	1322	1.5	1.39	1.29	26.35
40	1250	1788	3714	3.0	0.70	0.63	-14.49
41	1500	107	5333	1.0	14.06	4.02	26.13
42	1500	672	2023	1.5	2.23	1.94	40.91
43	1500	574	1091	2.5	2.61	2.39	84.90
44	1500	305	2339	4.0	4.92	3.55	51.09
45	1500	166	1882	4.0	9.03	5.77	70.88
46	1500	223	2083	4.0	6.74	4.59	61.32
47	1600	398	3750	2.0	4.03	2.74	32.07
48	1667	574	1091	3.0	2.90	2.65	100.18
49	2125	690	6400	1.0	3.08	2.10	22.43
50	3000	166	1882	2.0	18.07	11.53	150.58
Area-weighted average					3.18	1.98	24.19

Notes: [a] Operational costs composed of such items as the cost of electricity, the cost of repairs and necessary parts, and wage payments to labors. Wages are paid for such work as excavating channels, operating pumps, and supervising buyers' pump-use. Shadow wage rates (i.e. village level wages) are used for cost calculation when sellers do these works by themselves. [b] Total investment to irrigation systems consists of the costs of well digging, electric pump, and sprinkler systems. [c] $(5)=(1)/(2)$. [d] The depreciation cost of irrigation investment is estimated under the assumption of linear depreciation with a life of 20 years of irrigation systems. The formula becomes $(6)=(1)/((2)+((3)/20))$. [e] $(7)=[((1)-(2))/(3)]100$.

survey year happened to be a good harvest year. However, the village interview revealed that survey year was regarded as a year of normal weather. In all villages, the average yields over sample households fall within the ranges of the normal year average yields given at the village level interview: some villages close to the upper bound, and some close to the lower bound. We expect that the share buyers' payments in the survey year were not materially larger than those in the other normal years.

9) The interest rate of 5% is used here because this rate is applied to farming purposes and the interest rates lower than 5% are applied to non-farming purposes such as weddings and medical expenses.

10) See Eswaran and Kotwal [5] for the theoretical model.

11) The electric power for agricultural use is free in villages from A to C. A fixed amount is charged if a pump is beyond five horsepower in the villages from D to F.

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