Article

An Enquiry into Equity Impact of Groundwater Markets in the Context of Subsidised Energy Pricing: A Case Study

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Abstract

In India, groundwater over-extraction is often linked with subsidized electricity in the agricultural sector. Proponents of electricity subsidy argue that such a subsidy helped even the resource-poor farmers to have had access to groundwater irrigation. This article explores inter- and intra-generational equity implications of groundwater markets in the context of subsidized electricity where the market enables even non-well owners to access groundwater for irrigation. The study is based on survey data collected from two districts in the state of Madhya Pradesh, India. The sample includes farmers who use electricity- and diesel-powered pumps to lift groundwater. The structure of the existing water market is examined through the determination of the water price–cost ratio. The article finds that, in the short run, water markets improve accessibility to groundwater irrigation, particularly for marginal and small farmers. With the help of this, farmers are able to mitigate water-scarcity-related vulnerabilities. However, in the long run, electricity subsidy may have negative dynamic implications by causing over-exploitation of groundwater that reduces the volume of groundwater available for future agricultural use. In other words, this article finds that, in the initial phases of the development of the water markets, there are intra-generational equity implications. However, in the advanced phases, the unsustainable extraction of groundwater could lead to inter-generational inequities.

Keywords

Electricity subsidy, groundwater irrigation, water market, energy-water inter-linkage, equity.

Introduction

The Indian agriculture sector is heavily dependent on groundwater. Today, approximately 60 per cent of irrigated agriculture depends on groundwater resources (World Bank, 2012). More importantly, groundwater-driven agriculture rests, to a large extent, on access to electricity. For agricultural use, electricity in most of the Indian states is provided either free of cost or at a flat annual rate, based on pump capacity. Free or highly subsidized electricity implies that the private marginal cost of extraction for the farmers is zero or nearly so. This encourages farmers significantly to turn to groundwater use. Furthermore, farmers prefer groundwater as they have better control over quantity and the timing of water supply (Srinivasan & Kulkarni, 2014). This results in higher yields for groundwater-irrigated crops when compared to surface-water-irrigated crops (Dhawan, 1995; World Bank, 1998).

Electricity subsidy has significant long-term impacts on groundwater-resource sustainability, which, in turn, can have an impact on all farmers, especially small and marginal farmers who cannot exit the agricultural sector. The availability of subsidized electricity has facilitated the development of 'water market',[1] thereby enabling small and marginal farmers, who do not have the economic ability to sink borewells or own wells, to access groundwater for irrigation by purchasing water in such markets. In this context, water markets can improve equity by

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expanding the scope of groundwater access across different categories of farmers. Therefore, water markets can be an important institutional mechanism to increase access to groundwater irrigation, particularly for marginal and small farmers in India.

In this backdrop, this article examines implications of electricity subsidy on groundwater markets in the state of Madhya Pradesh (hereafter MP) in India. Such informal water markets in irrigation have emerged because formal water supply through canal systems has failed to deliver water as per farmers' preferences and requirements. As groundwater markets are localized, they provide a level of flexibility in terms of timing and quantity of water supply, which is not possible in the case of canal water. In this context, it becomes pertinent to understand how subsidizing one of the main inputs, namely electricity, can impact local informal water markets and what the consequent dynamic equity implications are. The structure of the existing water market is examined through water price–cost ratio analysis. Furthermore, the article discusses the various types of contractual agreements prevailing in the water market and also their equity implications. It also addresses the inter-generational equity as various studies indicate that subsidized electricity has led to dangerous levels of drop in water tables, thereby challenging the long-run sustainability of such a system. Nevertheless, the article argues that the abrupt elimination of groundwater subsidies can make small and marginal farmers vulnerable. Hence, subsidies may be phased out in parts along with other measures which can aid those farmers who do not have the economic ability to sink borewells.

The organization of this article is as follows. We first discuss theoretical debates in the literature on the linkage between energy pricing and groundwater use for agriculture and describe the methodology. It is followed by the description of the characteristics of the water market in the study area, including the explanation of various types of informal contractual agreements existing between buyers and sellers. We then examine the structure of the water market using a price–cost ratio analysis, including the exploration of the sellers' bargaining power in local water markets with respect to different criteria, such as sources of energy used (electricity vs. diesel), water availability (watershed vs. non-watershed) and modes of transaction in the water market (cash transaction vs. crop-sharing contract). Finally, we present the conclusion and policy implications.

Energy Pricing and Groundwater Use for Agriculture

Groundwater over-exploitation and electricity subsidy in India are complex issues. In the context of a developing country, a number of empirical studies have been conducted on the effects of energy prices on groundwater extraction. A shift from a metre-based tariff system to a flat-rate tariff system based on the motor horsepower in the late 1980s and early 1990s implied that the private marginal cost of groundwater extraction was nearly zero (Shah, Roy, Qureshi, & Wang, 2003). Consequently, over the next few decades, tubewell irrigation increased significantly, making groundwater dry and unfit for agriculture. Also, the cost of supplying electricity to the large and growing number of irrigation tubewell led to consistent losses for state electricity boards (Shah et al., 2003). In different parts of the country, a number of studies were conducted to analyze the negative impacts of electricity subsidies on groundwater and agricultural production (e.g., Badiani & Jessoe, 2013). Their results suggest that electricity subsidies have contributed to groundwater over-exploitation, increased groundwater extraction and shifted cropping patterns towards more water-intensive agricultural production, thus reducing the amount of groundwater available for future agricultural use. Regions that depend largely on diesel-powered tubewells, on the other hand, do not face the same problems.

As the private marginal cost of extraction of diesel-powered tubewells is higher and significant, the use of diesel tubewells was 40–150 per cent less HP hours compared to electricity-powered tubewells (Shah et al., 2004, p. 24). Empirical research shows that the flat-rate mode of pricing electricity consumption in the farm sector, which does not reflect the actual unit of consumption, creates incentive for the wasteful use of both electricity and groundwater (Kumar, Scott, & Singh, 2011; Kumar & Singh, 2001; Moench & Kumar, 1997; Palmer-Jones, 1994; Saleth, 1997). Zhu, Ringler, and Cai (2007), who have simulated the effects of energy prices on groundwater extraction in India, China, the USA and Vietnam, argue that subsidized energy for groundwater pumping is a major contributor to groundwater overdraft in India. Therefore, the electricity tariff policy on pro-rata basis has been increasingly advocated as a tool to influence groundwater use and withdrawal decisions of farmers.

Researchers advocate that a unit-rate (pro-rata) pricing system with the built-in positive marginal cost of pumping could bring about the efficient use of the resource (Kumar & Singh, 2001; Moench, 1995; Saleth, 1997; Shah, 1993). On the other hand, some argue that the levels of tariff at which demand becomes elastic to pricing are too high to be viable from political and socio-economic points of view (de Fraiture & Perry, 2002). Likewise, Narayanamoorthy (1997) argues that the influence of electricity tariff on the consumption of electricity and water would be too less as it constitutes a meagre portion of the total cost of cultivation. Also, Saleth (1997) asserts that the electricity tariff policy alone cannot be an effective tool for achieving efficiency, equity and sustainability in groundwater use. Shah (1993) emphasizes that, although the flat-rate system of electricity pricing would result in the low level of efficiency, it would produce high levels of social welfare as compared to the pro-rata system by enabling farmers to pump more water. Likewise, the pro-rata system of pricing might induce a higher efficiency of resource use, but produce a lower level of social welfare (including farmers' economic surplus) as compared to the flat-rate pricing system due to the reduction in demand for groundwater and the increase in the marginal cost of supplying energy.

There are also studies which show that subsidized electricity in the farm sector has triggered exponential growth in groundwater irrigation in India (Moench, 1995; Palmer-Jones, 1994; Shah, 1993). It also facilitated the development of water markets in India. As asserted by Shah (1993), water markets[2] provide one of the most promising institutional mechanisms for increasing access to irrigation from groundwater in India, particularly for marginal and small farmers. Over the years, these informal groundwater markets are growing in magnitude and gaining in significance in many parts of the country (Pant, 1992; Shah, 1993). In addition, water markets have been considered as providing incentives for both buyers and sellers to conserve water and distribute it in a more equitable manner (Easter et al., 1998; Meinzen-Dick, 1996; Saleth, 1991; Shah, 1993; D. R. Singh & R. P. Singh, 2006). Such markets facilitate water to be reallocated to more valuable uses without penalizing the existing water rights holder. More so, the option of selling also provides an incentive to conserve water and use it more rationally (Easter et al., 1998; Manjunatha, Speelman, Chandrakanth, & Huylenbroeck, 2011). It effectively increases the access of poor farmers towards groundwater resources (Meinzen-Dick, 1996; Saleth, 1991), thereby promoting equity in groundwater-dependent agriculture. In other words, water markets play a crucial role in catering to the irrigation needs of small and marginal farmers. Besides, the opportunity to sell groundwater can also make it profitable for farmers to invest in wells even if their own holdings are too small to use the full pumping capacity.

Shah (1991) reports that the expansion of irrigation through groundwater markets has led to increases in cropping intensity and the demand for agricultural labour, which ultimately benefit the landless and those who rely on wage labour for household income. Such markets are, however, difficult to regulate. Since water extractions are not restricted, it increases the sellers' *de facto* control over groundwater. As a result, in such an unregulated market, sellers potentially extract monopoly rent from buyers (Pant, 1992; Saleth, 1998; Shah, 1993).

The results from these studies show that the debate on the linkage between energy pricing and groundwater use in the farm sector in India is rather complex. There is then a need to understand the outcomes of groundwater markets in the context of electricity subsidies at the local and regional levels. This article, therefore, examines the groundwater market in a region that enjoys electricity subsidies vis-à-vis a region that largely uses diesel-powered tubewells for farming. The objective of the article is to understand the equity impact of such a market on small and marginal farmers through an examination of the structure of the market and the benefits accrued to their different categories. The article also examines the effects of groundwater markets across watershed and non-watershed regions as hydrological characteristics at the local level in combination with the groundwater tariff policy to determine the benefits to the farmers.

Data and Methodology

The field survey for the study was conducted in 2007 (August–October) in six villages of two districts, namely Vidisha and Guna, in MP. The dependence of farmers on groundwater for irrigation in MP has increased over the years, and wells are by and large a predominant source of irrigation. Unlike canals and tanks—the other two major sources of irrigation—the area under groundwater irrigation has increased significantly both in absolute terms and also in proportion to net irrigated area.[3] In the state, the net area irrigated by groundwater has increased considerably from 49 per cent in 1993[4] to 67 per cent in 2010–11[5] (Government of India, 2014). As per the Central Groundwater Board, there are 24 'over-exploited' blocks, 5 'critical' or 'dark' blocks and 19 'semi-critical' blocks[6] (Government of India, 2015).

The districts of Vidisha and Guna were selected purposively based on the source of energy for irrigation (electricity vis-à-vis diesel). The sample comprised of *diesel-using farmers* from Vidisha (111 farmers) and *electricity-using farmers* from Guna (109 farmers). Hence, a total of 220 farmers were selected on the basis of the stratified random-sampling technique to include all categories of farmers.[7] Essentially, the benefit of electricity subsidy in terms of the lower cost of groundwater extraction was availed only by the electricity-using farmers. Hence, the farmers who were using diesel were included in the sample as a control group. Diesel cost varies proportionally to the volume of water extracted and thus serves as a proxy for a unit rate or pro-rata energy-pricing system. Out of the 220 sample farmers, only 57 farmers (26%) participated in the water market, either as sellers (24) or as buyers (33). Limited participation in water market was essentially due to insufficient surplus water availability. Further analysis and discussion on structure and functioning of the water market in this article are, therefore, limited to these 57 farmer households.

The sample villages were selected purposely from both watershed and non-watershed regions[8] to capture the implications of energy pricing on water markets in areas endowed with varying groundwater potentials. The classification between groundwater-rich and -poor areas is essential, as the availability of groundwater itself is crucial for the development of groundwater irrigation. In the event of water scarcity, farmers cannot extract groundwater beyond a certain limit even if electricity is supplied free of cost. Therefore, besides comparing areas depending on different sources of energy, the impact of differential groundwater endowments has also been examined. The survey questionnaire collected data on the socio-economic characteristics of the farmer households, the agricultural and irrigation practices of the farmers and the details of buying/selling of water. Additionally, the key informants in each of the six villages provided data on village-level irrigation characteristics.

Water Markets: Structure and Functioning

Characteristics of Water Market

As the focus of the study is the use of groundwater for irrigation, the analysis has been confined to dry season (*rabi*) agricultural activities only when most volume of trading takes place. The main *rabi* crops cultivated using purchased groundwater in the region are wheat and chickpea. The survey data indicate that farmers in the study area primarily rely on groundwater for meeting their irrigational requirements. The prevalent means of extracting and distributing groundwater consist of private-well systems comprising electric pumps (in Guna), diesel pumps (in Vidisha) and water-conveyance facilities, such as ditches and rubber/plastic pipes. Table 1 summarizes the data collected on the irrigation status of the agricultural households in the survey villages.

As shown in Table 1, although the study area is mostly irrigated (79% of agricultural households irrigate their land), there is a clear discrepancy between the watershed (relatively water abundant) and non-watershed villages (relatively water scarce) in terms of accessibility to groundwater irrigation. In both the electricity- and diesel-using regions, watershed villages are largely irrigated (ranging from 80% to 100%) by a private-well system as compared to non-watershed villages. Only 38 per cent of households irrigate their land in the non-watershed village of the diesel-using region (Kundalpur village). This can be attributed to the inadequate groundwater availability and high cost of extraction associated with diesel use, which enables only rich farmers to invest in well irrigation. This hints at the scope of improving accessibility to groundwater irrigation through the development of water market whereby resource-poor small and marginal farmers could meet their irrigational requirements by purchasing water from large farmers with surplus groundwater in their wells. Also, the higher percentage of households relies on irrigated agriculture in the electricity-using villages of Guna (90%) as compared to the diesel using villages of Vidisha (68%).

There are 57 farmers in the study area, who participate in the water market, either as sellers (24) or buyers (33). Buyers are mostly small and marginal farmers, whereas large farmers with surplus water in their wells sell it at a certain price. Table 2 presents the category-wise composition of farmers participating in the water market in both the districts. The sample farmers can be broadly divided into four groups in terms of their irrigation status: (a) well owners who do not sell groundwater either due to topographical and conveyance constraints or inadequate water availability in their wells (117 farmers), (b) well owners who sell surplus groundwater after irrigating their own plots (24 farmers), (c) water buyers who do not own wells (33 farmers) and (d) farmers who neither own well nor purchase water for irrigation and rely on rainfed irrigation (46 farmers). The fourth category of farmers is redundant in the analysis as the investigation is confined to groundwater irrigation only and, therefore, this category is out of purview of the study.

Most importantly, the sellers and buyers in the study area are mutually exclusive groups, that is, sellers do not purchase groundwater from other sellers.[9] No buyer in the study area owns a well. Interviews with the village key informants helped to identify matched pairs of sellers and buyers. The survey also indicates that buyers do not purchase groundwater from multiple sellers, whereas some sellers provide groundwater to more than one buyer.

Functioning of Water Market

The summary indicators of the functioning of water market in both the electricity- and diesel-using villages are given in Table 3. As can be seen from the table, every seller in the diesel-using villages serves more number of buyers (~33%) than a seller in the electricity-using villages and also irrigates a greater area of the buyer's land. Nevertheless, only 35 per cent of the buyer's total agricultural land is

Table 1. Groundwater Irrigation Status of Agricultural Households

Particulars	*Guna*: Electricity				*Vidisha*: Diesel				Overall Total
	Kailashpura (WS)[1]	Sohankhedi (WS)	Bhagwanpur (NWS)[2]	Total	Lalatora (WS)	Khairkhedi (WS)	Kundalpur (NWS)	Total	
Number of agricultural households	36 (18)[3]	35 (17.5)	38 (19)	109 (54.5)	34 (17)	40 (20)	37 (18.5)	111 (55.5)	220 (100)
Number of well owners (non-sellers)	27 (23)	26 (22)	14 (12)	67 (57)	23 (20)	19 (16)	8 (7)	50 (43)	117 (100)
Number of well owners (water sellers)	4 (17)	3 (12.5)	7 (29)	14 (58)	3 (12.5)	5 (21)	2 (8)	10 (42)	24 (100)
Number of water buyers	5 (15)	5 (15)	7 (21)	17 (51)	4 (12)	8 (24)	4 (12)	16 (48)	33 (100)
Number of farmers relying on rainfed agriculture	0 (0)	1 (2)	10 (22)	11 (24)	4 (9)	8 (17)	23 (50)	35 (76)	46 (100)
Percentage of households relying on irrigated agriculture	100	97	74	90	88	80	38	68	79

Source: Primary survey.
Notes: [1] WS: Watershed village.
[2] NWS: Non-watershed village.
[3] Figures in parentheses represent percentage.

Table 2. Water Market Participation

Participants[1]	*Guna:* Electricity					*Vidisha:* Diesel					Total				
	Marginal	Small	Medium	Large	Total	Marginal	Small	Medium	Large	Total	Marginal	Small	Medium	Large	Total
Well owners[2]	11 (44)[4]	35 (71)	18 (100)	17 (100)	81 (74)	4 (17)	2 (10)	18 (60)	36 (97)	60 (54)	15 (31)	37 (53)	36 (75)	53 (98)	141 (64)
Sellers	0	3	7	4	14	0	0	1	9	10	0	3	8	13	24
Non-sellers[3]	11	32	11	13	67	4	2	17	27	50	15	34	28	40	117
Non-well owners	14 (56)	14 (29)	0 (0)	0 (0)	28 (26)	19 (83)	19 (90)	12 (40)	1 (3)	51 (46)	33 (69)	33 (47)	12 (25)	1 (2)	79 (36)
Buyers	6	11	0	0	17	0	8	8	0	16	6	19	8	0	33
Non-buyers	8	3	0	0	11	19	11	4	1	38	27	14	4	1	46
Total	25 (100)	49 (100)	18 (100)	17 (100)	109 (100)	23 (100)	21 (100)	30 (100)	37 (100)	111 (100)	48 (100)	70 (100)	48 (100)	54 (100)	220 (100)

Source: Primary survey.
Notes: [1] Farmers are classified broadly into four categories: Marginal (<1 ha), small (1 to <2 ha), medium (2 to <4 ha) and large (≥4 ha).
[2] There are no buyers in the study area who own a well.
[3] Some sellers do not sell water, as they do not have excess water after completing irrigation of their own plots or due to topographical and other constraints.
[4] Figures in parentheses represent percentage in totals.

Table 3. Summary Indicators of the Working of Groundwater Market

Particulars	*Guna*: Electricity Users		*Vidisha*: Diesel Users	
Number of sellers	14		10	
Number of buyers	17		16	
Number of buyers per seller	1.2		1.6	
Total buyers' area irrigated (*acres*)[1]	25.78 (54.45)		30.02 (35.04)	
Average buyers' area irrigated per seller (*acres*)	1.84		3	
Average hours of water used by buyers per acre	25		38	
Average acre inch of water used per acre by buyer				
(i) Wheat	16.44		17.89	
(ii) Chickpea	5.14		5.78	
Average hourly[2] water charge [INR/h]	Cash[3]	Crop Share[4]	Crop Share[5]	
	WS	NWS	WS	NWS
(i) Wheat	30.00	48.00	51.50	49.00
(ii) Chickpea	27.00	40.50	45.00	42.50
Average per acre water charge [INR/acre]				
(i) Wheat	678.00	2174.00	2587.00	2210.00
(ii) Chickpea	678.00	1190.00	1485.50	1280.00

Source: Primary survey.

Notes: [1] Figures in parentheses represent percentage of buyers' total area irrigated by seller.

[2] Hourly charge is estimated based on total hours of irrigation provided with purchased water by the seller and total payment paid for it.

[3] Flat charge cash payment for purchased water (i.e., INR/acre/irrigation). Farmers provide two irrigations only as more number of irrigation implies higher water charge.

[4] A certain proportion of the output is paid to the seller as charge for purchased water. It varies from one-third to one-fifth of the total produce.

[5] In the diesel-using villages, no cash-based contract exists. However, in electricity-using villages, cash payment is found only in the watershed villages, whereas crop-sharing contract exists in the non-watershed village.

irrigated by all sellers in the diesel-using region as against 54.45 per cent in the electricity-using region, which indicates that water markets are somewhat more developed in the electricity-using area. In addition, sellers in the diesel-using villages have better bargaining positions in determining water price, as more number of alternative buyers exists for them whereby they might threaten the current buyers by means of their possible withdrawal from the water-selling contract. Hence, it could be argued that the availability of cheap subsidized electricity facilitates, to some extent, the development of water markets, thereby enabling non-well owners to access groundwater for meeting their irrigational requirements by purchasing from those with surplus water.

Contractual Agreements in Water Market

Now, we will discuss the different types of contractual agreements existing in the water market of the study area with regard to the sale and purchase of water.[10] Broadly two types of transactions are observed in the water market, namely cash payments and output-sharing contracts (crop sharing). In cash-based transactions, buyers pay a fixed price for each irrigation provided on per acre of land. This type of contract exists in the watershed villages of the electricity-using district of Guna (Kailashpura and Sohankhedi). Under output-sharing contracts, buyers pay a certain proportion of their crop output to the seller as water rent.[11] This type of contract exists in both the watershed and non-watershed villages of the diesel-using district of Vidisha (Lalatora, Khairkhedi and Kundalpur) and also in the non-watershed village of the electricity-using district (Bhagwanpur).

Cash transactions and output-sharing contracts account for 30 and 70 per cent of the total contracts, respectively. As indicated in Table 3, water charge (per acre/hour) is higher for crop-sharing contracts when compared with case transactions. Crop-sharing contracts involve the transfer of production risk partially from buyers to sellers. Hence, a risk premium transfer could essentially take place in the form of higher prices (Hayami & Otsuka, 1993). Also, for output-sharing contracts, buyers pay water fee only after the harvest and, therefore, an implicit interest premium could be included in the water price.

It is also important to note that crop- or output-sharing arrangement usually leads to an *assured* market for water since water sale or purchase is for the entire season. Water charge, as mentioned earlier, is levied on the basis of the market value of one-third (for wheat) or one-fifth (for chickpea) of the crop yields. Here, bargaining power usually rests with the seller even though the risk of crop loss is equally shared between the seller and the buyer. Higher bargaining power results in a higher rate charged for per acre water used compared to the rate charged on an hourly basis. Charging of water based on number or hours of irrigation provided per acre of land (cash transaction), on the other hand, usually leads to an ad hoc market since the buyer has the option to buy only as and when required.

Precisely, crop-sharing contracts are more expensive than cash transactions in the water market due to the implicit interest payment and associated risk premium. The study also finds that crop-sharing contracts are mostly prevalent in the diesel-using area where the marginal cost of extraction is high. This indicates that electricity subsidy encourages the development of water markets based on cash transactions wherein water charge is relatively lower. However, the ultimate water charge is essentially determined by the bargaining position of sellers and buyers, which in turn depends on the structure of the water market. This extends the discussion to the next section of the article, which examines the structure of the water market in the study area by comparing the water price–cost under different forms of market.

Structure of Water Market

In developing countries, it has been observed that there is the absence of competitive markets in transactions of groundwater between well owners and buyers (Campbell, 1995; Kahnert & Levine, 1993). Topographical constraints, capacity of water pump and length of conveyance facilities, such as pipelines, limit the deliverable area. Therefore, the number of potential buyers that owners of irrigation systems could expect is physically limited, as is the number of potential sellers that a non-owner could anticipate. Usually, the owner and non-owner in a close location becomes a pair of seller and buyer for water transactions, and the price is determined under bilateral bargaining between them.

According to standard market theory, the structure of a market influences the conduct of sellers and buyers. Conventionally, the market structure is examined through the estimation of price–cost ratio. Shah and Ballabh (1997) assert that water markets in areas with high price–cost ratios are not competitive but monopolistic. On the other hand, even though Fujita and Hossain (1995) obtained high price–cost ratios, they deny sellers' monopolistic pricing as the rate of return to capital investment in irrigation systems (69%) is close to the interest rate in the informal financial market (38–61%). Hence, they conclude that if the risk of investment in irrigation systems is taken into consideration, then prices that the sellers charge may be economically reasonable. However, it does not necessarily support the existence of competitive markets, that is, the existence of one single price. A competitive market structure is essentially characterized by the existence of insignificant price differentials under different forms of water market.

Water Price–Cost Ratio

In the light of the above discussion, the water price–cost ratio in the study area has been calculated to identify the structure of the existing water market. To calculate the water price–cost ratio, first the per acre water charge (price) is calculated. For crop-sharing contracts, it is equivalent to the per acre value of crop output produced and paid to the seller. For cash transactions, water price is the total charge paid by buyers to completely irrigate an acre of land. The operational cost or variable cost per acre (INR/acre) is composed of energy cost, cost of repairs, conveyance cost, etc. Table 4 presents the detailed price–cost structure of the water market in the study area. The ratio of water price to variable cost is then obtained by dividing per acre water charge by variable cost per acre.

As can be seen from Table 4, the estimated overall average price–cost ratio is 1.26, which is modest compared to other earlier studies on the water market conducted in different parts of India.[12] Furthermore, in the following points, variation in the price–cost ratio (indicating sellers' bargaining power in the water market) has been examined with respect to different criteria, such as sources of energy used (electricity vs. diesel), water availability (watershed vs. non-watershed), modes of transaction in the water market (cash transaction vs. crop-sharing contract), etc. (see Table 5).

Source of Energy

Table 5 shows that the water–price ratio is comparatively higher for diesel users (1.45) than electricity users (1.12). In villages that use diesel, the water market tends to be less developed due to the associated high cost of extraction, which limits the deliverable area and also the number of potential buyers and sellers, thereby leading to greater price variations across the region. Consequently, the limited number of existing sellers is better off with regard to their bargaining power in the water market. This results in relatively higher water price, which in turn leads to lower demand for irrigation water, thereby reducing the pumping rate (hours pumped per year). Besides, the cost structure of

Table 4. Water Price–Cost Ratio

Sellers	Area Irrigated by Buyer (acre)	Total Groundwater Price (INR)	Total Operational Cost (INR)	Water Price/Acre[1] (INR)	Operational Cost/Acre[2] (INR)	Ratio of Water Price to Operational Cost
1	4.73	3185	3036	674	642	1.05
2	1.58	1049	1019	664	645	1.03
3	2.63	1762	1728	670	657	1.02
4	2.10	1394	1268	664	604	1.10
5	2.90	1984	1889	684	651	1.05
6	2.37	1622	1515	684	639	1.07
7	1.58	1090	1028	690	651	1.06
8	1.05	1607	1385	1530	1391	1.16
9	1.05	2600	2131	2476	2030	1.22
10	1.05	1615	1357	1538	1293	1.19
11	1.05	2600	2167	2476	2063	1.20
12	1.05	2145	1818	2043	1732	1.18
13	1.58	2585	2248	1636	1423	1.15
14	1.05	2600	2167	2476	2063	1.20
15	3.75	8040	6091	2144	1624	1.32
16	1.25	3152	2425	2522	1940	1.30
17	3.76	7415	5534	1972	1472	1.34
18	3.13	7630	5780	2438	1847	1.32
19	3.13	8125	5490	2596	1754	1.48
20	2.50	6825	4432	2730	1773	1.54
21	5.00	13325	8328	2665	1666	1.60
22	1.88	5200	3421	2766	1820	1.52
23	3.13	6650	4209	2125	1345	1.58
24	2.50	5200	3421	2080	1368	1.52
Average						**1.26**

Source: Primary survey.

Notes: [1] Water price implies the total charge per acre paid by buyers for irrigating their land.
[2] Operational cost refers to the variable costs associated with water sale, i.e., energy cost, repair cost and conveyance cost.
[3] Samples [1–7] pay water charge in cash (flat charge at INR/h/irrigation), while the rest follow output-sharing contract.
[4] Samples [1–14] are electricity users and the rest use diesel.

Table 5. Water Price–Cost Ratio (Average)

Particulars	Types	Ratio of Water Price to Operational Cost
Source of energy	Electricity	1.12
	Diesel	1.45
Mode of transaction	Cash payment	1.05
	Crop share contract	1.34
Groundwater availability	Relatively water abundant [Watershed]	1.25
	Relatively water scarce [Non-watershed]	1.27
Overall		**1.26**

Source: Primary survey.

groundwater pumping often discourages owners of diesel irrigation pumps to adopt the price-cutting strategy to increase pumping (under-utilization of pump capacity). Thus, the utilization of additional capacities and groundwater use intensity remain low. On the other hand, electric irrigation pumpsets (based on flat-rate pricing) are likely to run for longer hours (higher pumpage rate), irrigate more areas and serve a larger number of farmers in spite of electricity uncertainty. Importantly, water buyers' cost of irrigation is likely to be more sensitive to the price structure of energy than that of sellers. So, even if power subsidy benefits pump owners (who are often large and medium farmers) more, its absence and hence dependence on diesel pumpsets hurts poor marginal and small water buyers the most.

Mode of Transaction

The water price–cost ratio is found to be higher for the farmers following output-sharing contracts (1.34) than farmers paying water rent in cash (1.05). The contract

Table 6. Annual Net Returns per Acre across Farmers' Categories (INR/acre)

	Electricity		Diesel	
Farmer Category	Watershed	Non-watershed	Watershed	Non-watershed
Marginal	3129	2725	3304	2514
Small	4305	2929	3511	1122
Medium	4143	3694	3289	2474
Large	4658	4300	3510	3145
Total	4445	3566	3460	3032

Source: Primary survey.

theory literature argues that output-sharing contracts could be inequitable as rent payment is higher than other forms of contracts. 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 & Otsuka, 1993). In addition, since the output-sharing buyers pay the water fee only after the harvest, an implicit interest premium could also be included in the water price. Therefore, crop or output-sharing contracts are more expensive, and sellers are likely to have more bargaining power by means of greater control on irrigation services.

Groundwater Potential

The average price–cost ratio is slightly higher in the water-scarce non-watershed villages (1.27) when compared to the relatively water-abundant watershed villages (1.25), thereby implying better bargaining power of sellers in the water market. In water-scarce areas, less number of alternative potential sellers is likely to exist due to the inadequate availability of groundwater. Therefore, the existing sellers enjoy more bargaining power and consequently charge higher water rent. In addition, establishing wells is rather expensive and risky in these areas (wells are prone to dry up or fail completely). So the density of wells is low and, hence, the existing sellers have better bargaining power. This reveals that groundwater price often varies due to regional variation in groundwater potentials.

The above discussion indicates that a number of factors influence the bargaining power of sellers and buyers and, hence, the structure of the water market in a given regional setting. These may be broadly categorized as physical (groundwater potential), institutional and economic (subsidized electricity and modes of transaction in water market), etc. In addition, individual characteristics of sellers/buyers (e.g., farming experience, farm management ability, etc.) could also influence groundwater price formation. However, because of the small sample of water market participants in the study area, these attributes could not be addressed in the present study. In the case of sellers who use electricity, prices charged per hour of pumping is substantially lower than diesel users irrespective of groundwater-resource potentials in the region. This is because flat-rate charges for power consumption imply zero incremental cost of pumping. As a consequence, electric pump owners have a tendency to maximize the utilization of their pump capacity by selling water. To summarize, the provision of electricity subsidy entails crucial short-term welfare benefits to small and marginal farmers through the development of competitive water markets wherein water charge paid by buyers is relatively lower than diesel users. The article also finds that the water market in the electricity-using region is characterized by cash transactions between sellers and buyers. This implies that contractual agreements based on cash transactions have lower water rent as compared to crop-sharing contracts. Hence, it may be argued that electricity subsidy encourages the development of somewhat competitive water markers, thereby promoting equity across different categories of farmers, especially in the short run. In Table 6, the average of annual net returns from groundwater irrigation across different farmer categories is presented. Farmers operating in water market in the context of electricity subsidy, in general, fare better than those operating in water markets backed by diesel-powered tubewells. All categories of farmers in a watershed region have higher returns per acre as compared to those in the non-watershed regions. Overall, those farmers who were located in a watershed region and participated in the subsidized electricity-based water market fared better than other categories of farmers.[13] These outcomes are assigned to the very low/zero marginal cost of extraction associated with the annual flat-rate-based electricity charge.

Conclusion and Policy Implications

This article substantiates the fact that groundwater markets, which are informal institutional arrangements, largely improve accessibility to groundwater irrigation, particularly for marginal and small farmers who do not own wells. More so, the availability of subsidized electricity facilitates the development of such markets, thereby promoting equity by enabling resource-poor farmers to purchase groundwater from large farmers with surplus resource. The estimated average price–cost ratio is modest in the study area, which indicates a somewhat competitive market structure. Furthermore, the comparison of the water price–cost ratios for different groups of farmers provides some interesting insights. The ratio shows that buyers (vis-à-vis sellers) in subsidized electricity water markets have more bargaining power as compared to the buyers in diesel-powered water markets. Also, crop-sharing contracts prevailing predominantly in the diesel area are more expensive than cash transactions because of the associated risk premium and implicit interest payment. Hence, the price–cost ratio under crop-sharing contracts is higher wherein sellers enjoy more bargaining power. In other words, electricity subsidy encourages the development of water markets based on cash transactions wherein water charge is relatively lower. This entails crucial equity implications across different categories of farmers. The examination of annual net returns per acre across the farmer categories shows that, in general, marginal and small farmers in watershed regions with subsidized-electricity-driven groundwater markets were better off as compared to small and marginal farmers from non-watershed regions with diesel-driven groundwater markets.

The results indicate that subsidizing electricity can induce equity between vulnerable and resource-rich farmers in the short run. This is important especially in the context of farmers who are facing increasing water vulnerabilities, such as farmers in the tail ends of irrigation projects and farmers in areas where formal irrigation systems have not yet penetrated. However, studies indicate that subsidized electricity has led to dangerous levels of drop in the water tables, thereby challenging the long-run sustainability of such a system. Nevertheless, the abrupt elimination of groundwater subsidies can make small and marginal farmers vulnerable. Hence, the study suggests that subsidies can be removed in a phased manner and in tandem with alternative security nets, such as providing reliable canal water (by increasing maintenance), reviving tank irrigations and associated welfare benefits, such as easy to access crop insurance and creating markets for water-saving crops. In other words, subsidies can be phased out in parts along with other measures which can aid those farmers who do not have the economic ability to sink borewells.

Notes

1. 'Water market' refers to a localized village-level institutional set-up through which well owners with excess water in their wells supply water to other members of the community at a certain price (Shah, 1993).
2. Since well ownership is largely limited to a small proportion of large and affluent farmers, the sale and purchase of groundwater through informal water market offer the opportunity to use groundwater for other farmers as well.
3. Indian Agricultural Statistics, *Various Issues*, Ministry of Agriculture, Government of India.
4. http://www.fao.org/nr/water/espim/country/india/index.stm (Accessed on 1 September 2015).
5. http://mospi.nic.in/Mospi_New/upload/SYB2014/ch12.html (Accessed on 1 September 2015).
6. 'Overexploited' implies more than 100 per cent exploitation, that is, the annual groundwater extraction exceeds the annual replenishable resource. 'Dark' implies that the stage of groundwater development is above 85 per cent and within 100 per cent of annual replenishable resource. 'Semi-critical' implies that the stage of groundwater development is between 70 and 100 per cent. Source: http://cgwb.gov.in/gw_profiles/st_MP.htm (Accessed on 31 August 2015).
7. Farmers are classified broadly into four categories: marginal (less than 2.5 acres), small (2.5 acres to less than 5 acres), medium (5 acres to less than 10 acres) and large (10 acres or more).
8. Availability of groundwater is assumed to be more in the watershed region due to the presence of recharge facilities.
9. However, some studies (e.g., Shah, 1993) show that in other areas of India, the owners who have multiple plots at different places sometimes buy water from other owners who have wells nearby.
10. All buyers cultivate self-owned plots. There is no case wherein a landlord provides water to a tenant as a part of an interlinked land tenancy contract. Similarly, there is no interlinked input transaction, where the buyer provides labour in return for water. These facts indicate that contracts entered into are strictly for groundwater. The water market participants choose a contract solely for groundwater transaction depending upon the bargaining power of sellers and buyers.
11. The output-sharing rate varies from one-fifth to one-third of the total produce or crop output.
12. See Shah (1993), Shah and Raju (1987), Shah and Ballabh (1997) and Fujita and Hossain (1995).
13. This is true for all categories except that marginal farmers in a watershed where diesel-powered tubewells drive the market seem to be doing a little better than those farmers who were located in a watershed region where subsidized electricity drives the water market.

References

Badiani, R., & Jessoe, K. (2013). *The impact of electricity subsidies on groundwater extraction and agricultural production* (Working Paper). Davis, CA: University of California.

Campbell, D. E. (1995). *Design and operation of smallholder irrigation in South Asia* (Vol. 256). World Bank Publications.

De Fraiture, C., & Perry, C. (2002, June). Why is irrigation water demand inelastic at low price ranges. In *Conference on Irrigation Water Policies: Micro and Macro Considerations* (pp. 15–17).

Dhawan, B. D. (1995). Magnitude of groundwater exploitation. *Economic and Political Weekly, 30*(14), 769–775.

Easter, K. W., Rosegrant, M. W., & Dinar, A. (1998). *Markets for water: Potential and performance* (Vol. 15). Springer Science & Business Media.
Fujita, K., & Hossain, F. (1995). Role of the groundwater market in agricultural development and income distribution: a case study in a northwest Bangladesh village. *The Developing Economies*, *33*(4), 460–463.
Government of India. (2014). *Indian agricultural statistics* (various issues). New Delhi: Directorate of Economics and Statistics, Ministry of Agriculture.
Government of India. (2015). *State profile: Ground water scenario of Madhya Pradesh*. Faridabad: Central Ground Water Board, Ministry of Water Resources. http://cgwb.gov.in/gw_profiles/st_MP.htm
Hayami, Y., & Otsuka, K. (1993). *The economics of contract choice: An agrarian perspective*. Clarendon Press.
Kahnert, F., and G. Levine, (eds.) (1993). *Groundwater irrigation and the rural poor: options for development in the Gangetic basin, A World Bank Symposium*. Washington DC: The World Bank.
Kumar, M. D., Scott, C. A., & Singh, O. P. (2011). Inducing the shift from flat-rate or free agricultural power to metered supply: Implications for groundwater depletion and power sector viability in India. *Journal of Hydrology, 409*(1), 382–394.
Kumar, M. D., & Singh, O. P. (2001). Market instruments for demand management in the face of scarcity and overuse of water in Gujarat. *Water Policy, 3*(5), 387–403.
Manjunatha, A. V., Speelman, S., Chandrakanth, M. G., & Huylenbroeck, G. V. (2011). Impact of groundwater markets in India on water use efficiency: A data envelopment analysis approach. *Journal of Environmental Management*, *92*(11), 2924–2929.
Meinzen-Dick, R. S. (1996). *Groundwater markets in Pakistan: participation and productivity* (Vol. 105). International Food Policy Research Institute.
Moench, M. (Ed). (1995). When good water becomes scarce: Objectives and criteria for assessing over-development in groundwater resources. *Groundwater availability and pollution: The growing debate over resource condition in India*. Ahmedabad: VIKSAT.
Moench, M., & Kumar, D. (1997). Distinction between efficiency and sustainability: The role of energy prices in groundwater management. In A. Agarwal (Ed.), *The challenge of balance: Environmental economics in India*. New Delhi: Centre of Science and Environment.
Narayanamoorthy, A. (1997). Impact of electricity tariff policies on the use of electricity and groundwater: Arguments and facts. *Artha Vijnana, 39*(3), 323–340.
Palmer-Jones, R. (1994). Groundwater markets in South Asia: A discussion of theory and evidences. In M. Moench (Ed.), *Selling water: Conceptual and policy debates over groundwater markets in India*. Ahmedabad: VIKSAT.
Pant, N. (1992). *New trends in Indian irrigation: Commercialisation of groundwater*? New Delhi: Ashish Publishing House.
Pfeiffer, L & Lin, CYC. (2013). *Property rights and groundwater management in the high plains aquifer*. Working paper, University of California at Davis. Retrieved 04 July 2015, from http://www.des.ucdavis.edu/faculty/Lin/water_temporal_property_rts_paper.pdf
Saleth, R. M. (1991). Factors affecting farmers' decision to buy groundwater: Empirical evidence from the Indo-Gangetic Region. *Indian Journal of Agricultural Economics*, *46*(3), 349–354.
Saleth, R. M. (1997). Power Tariff Policy for Groundwater Regulation: Efficiency, equity and sustainability. *Artha Vijnana, 39*(3), 312–322.
Scott, C. A., & Shah, T. (2004). Groundwater overdraft reduction through agricultural energy policy: Insights from India and Mexico. *International Journal of Water Resources Development, 20*(4), 149–164.
Shah, T., & Raju, K. V. (1988). Ground water markets and small farmer development. *Economic and Political Weekly*, *23*(13), A23–A28.
Shah, T. (1991). Water markets and irrigation development in India. *Indian Journal of Agricultural Economics, 46*(3), 335–348.
Shah, T. (1993). *Groundwater markets and irrigation development: Political economy and practical policy*. Mumbai: Oxford University Press.
Shah, T., & Ballabh, V. (1997). Water markets in north Bihar: Six village studies in Muzaffarpur District. *Economic and political Weekly*, *27*, A183-A190.
Shah, T., Giordano, M., & Wang, J. (2004). Irrigation institutions in a dynamic economy: What is China doing differently from India?. *Economic and Political Weekly*, 3452–3461.
Shah, T., Roy, A. D., Qureshi, A. S., & Wang, J. (2003, May). Sustaining Asia's groundwater boom: An overview of issues and evidence. *Natural Resources Forum, 27*(2), 130–141.
Singh, D. R., & Singh, R. P. (2006). Structure, determinants and efficiency of groundwater markets in western Uttar Pradesh. *Agricultural Economics Research Review, 19*(1), 129–144.
Srinivasan, V., & Kulkarni, S. (2014). Examining the emerging role of groundwater in water inequity in India. *Water International, 39*(2), 172–186.
World Bank. (1998). *India: Water resources management sector review*. Washington, DC and New Delhi: World Bank and Government of India.
World Bank. (2012, March 6). *India Groundwater: A valuable but diminishing resource*. Retrieved from https://www.worldbank.org/en/news/feature/2012/03/06/india-groundwater-critical-diminishing
Zhu, T., Ringler, C., & Cai, X. (2007). *Energy price and groundwater extraction for agriculture: Exploring the energy–water–food nexus at the global and basin levels*. International Conference of Linkages between Energy and Water Management for Agriculture in Developing Countries, Hyderabad, India.