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Water Policy Program

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Water Policy Research

Highlight

Impact of Water Prices and Volumetric Water Allocation on Water Productivity:
Comparative Analysis of Well Owners, Water Buyers and Shareholders

M. Dinesh Kumar

The paper presents a theoretical model to analyze farmers' response to changes in power tariff and water allocation regimes vis-à-vis energy and groundwater use. It validates the model by analyzing water productivity in groundwater irrigation under different electricity pricing structures and water allocation regimes. Water productivity was estimated using primary data of gross crop output, cost of all inputs, and volumetric water inputs.

The analysis shows that unit pricing of electricity influences groundwater use efficiency and productivity positively. It also shows that the level of pricing at which demand for electricity and groundwater becomes elastic to tariff are socio-economically viable. Further, water productivity impacts of pricing would be highest when water is volumetrically allocated with rationing.

Impact of Water Prices and Volumetric Water Allocation on Water Productivity: Comparative Analysis of Well Owners, Water Buyers and Shareholders[1]

Research Highlight Based on a Paper With the Same Title

Several regions of India today face the threat of depleting groundwater resources. Agricultural pumping accounts for 31.4 percent of power consumed in India. Power consumption has recorded a steady increase during the past decade mainly owing to depletion of groundwater. The poor financial working of many state electricity boards (SEBs) is attributed to highly subsidized power made available to the farm sector and power thefts. Deteriorating financial condition severely limits the ability of SEBs to supply good quality power to the farm sector. The past decade has seen wide ranging debates on the potential linkage between electricity pricing and groundwater use for irrigation, especially the implication of electricity prices for access equity, efficiency, and sustainability in groundwater use. The debates are characterized by differing and often diametrically opposite views on the potential impact of power tariff changes on access equity, efficiency and sustainability. Not much of consensus exists about appropriate tariff structures, which generate efficiency in resource use, equity in access to groundwater, and sustainability of resource use. Some scholars have argued that even an imperfect system of groundwater rights will have more sustainable benefits than a most perfectly designed power tariff structure. Unfortunately, these debates are based on theoretical reasoning and some practical considerations, and not backed by empirical analysis.

Some scholars argue that even an imperfect system of groundwater rights will have more sustainable benefits than a more perfectly designed power tariff structure.

Objectives

The study was carried out to analyze the potential impact of different modes of electricity pricing on productivity of groundwater use. The modes of pricing are: [1] pump horsepower based pricing of electricity in which the marginal cost of abstraction of groundwater is almost nil; [2] pro rata pricing of electricity in which the marginal cost of pumping is positive and becomes closer to the cost of electricity required to pump out unit volume of water; and [3] the marginal cost of electricity is positive, but the amount of water and electricity to which farmers are entitled is fixed. The study covers well irrigators of north Gujarat comprising well owners, water buyers, shareholders and share croppers.

Since there are not many examples wherein the farmers pay for electricity on unit consumption basis, farmers who buy water from well owners on hourly charges are used as the proxies. The hourly water charge can be treated as hourly electricity charge using the assumption that the water charge which farmers pay is the sum total of the share of the fixed investment required for installing tubewells and the variable cost of pumping. The cases of tubewell partnerships where water

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allocation to different shareholders is fixed in volumetric terms and based on the land holding of the farmer are taken as the proxies for rationed water and electricity supply. The assumption is that current allocations are much lower than the amount of water required by farmers to grow water intensive crops, given the fact that there are many farmers in the command.

A Model for Analyzing Farmer Behaviour in Response to Different Pricing and Allocation Regimes

Figure 1 provides a model for analyzing farmer behavior in response to different pricing regimes. The model essentially provides a framework for analyzing the differential impact of market-based instruments such as the unit pricing of electricity and volumetric water use rights on energy use efficiencies and physical and economic efficiencies of water use in agriculture, as against that of the flat rate system of pricing and absence of property right regimes in water. The model suggests that the lowest water use efficiency—physical and economic—is obtained under the flat rate system of pricing, where farmers continue to apply irrigation until the net marginal productivity (equal to gross marginal productivity in this case because of zero marginal cost of electricity and irrigation) becomes zero. The net marginal productivity curve will be AX_2. The selling price of water is expected to be lowest in such a situation, because of the presence of competitive markets.

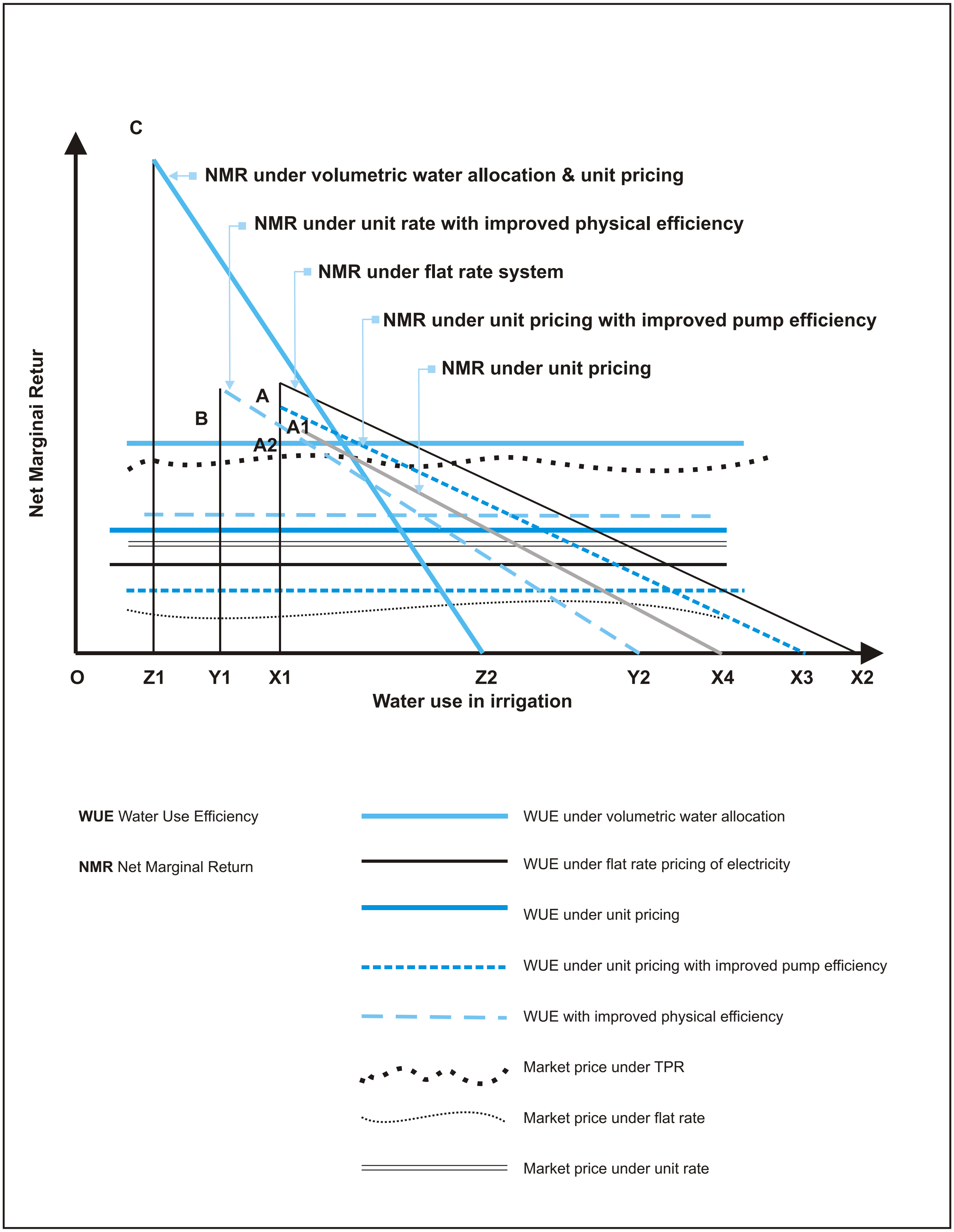
When changed to unit pricing, farmers might make some improvements in pump efficiency and physical efficiency of water use in irrigation. With price shifts, the selling price of water is also expected to rise slightly. Even though water markets exist, farmers may not be confronted with the real opportunity cost of using water for two reasons: [1] mismatch between demand for water and the ability of farmers to supply water; and [2] the average net economic return from irrigated crops might be still higher than the price at which water is sold.

The model suggests that the lowest water use efficiency— physical and economic—is obtained under the flat rate system of pricing, where farmers continue to apply irrigation until the net marginal productivity becomes zero.

Hence, farmers would continue to grow water intensive crops since water and energy are not limiting factors. Without any efficiency improvements, the net marginal productivity curve would take a dip to A_2X_4 as the net marginal return would become zero at much lower level of irrigation itself (X_4 instead of X_2) because of the induced marginal cost of electricity and water. The attempt, therefore, would be to either reduce electricity use per unit of water pumped through improvements in pump efficiency, and maximize the level of irrigation (in which case the curve would be pushed to A_1X_3 from A_2X_4) or use water efficiently in which case the curve would be shifted to a new position BY_2. In the latter two cases, water productivity would be slightly higher than in the first case.

If water is allocated on volumetric basis with rationing, farmers' preference would shift to crops that yield higher returns per unit of water consumed, the reason being that the price at which water would be traded would be highest as water becomes a limiting factor for generating wealth out of agriculture. Since price would represent the opportunity cost of using water, theoretically it should induce farmers to take those crops which give similar or a higher return per unit volume of water. The net marginal productivity curve would take a new position of

Figure 1: Farmers Response to Changing Price Structure and Water Allocation Regimes



CZ_2, with the average net productivity being higher than the price of water. Economic efficiency of water use will eventually rise. The expected overall impact of differential pricing of electricity and volumetric water allocation on the marginal cost of water/energy use, water price, and water productivity is presented in Table 1. The objective of the present study is to validate the model through analysis of empirical data on irrigation water application and water productivity.

Results and Discussion

Comparison of Irrigation-Gross Return Linkage

Wheat was taken as the sample crop for analysing the linkage between irrigation water application and gross return under different price and water allocation regimes. The results are presented in Table 2, which shows that shareholders represent the lowest level in the irrigation water use regime

Table 1: Impacts of Differential Pricing of Electricity and Volumetric Water Allocation Regimes

Energy Pricing/ Water Allocation Policy	Example for Case Study	Marginal Cost of Pumping & Use	Energy Supply Regime	Water Supply Regime	Water Price	Net Water Productivity in Crop Production
Flat rate pricing of electricity	Tube Well owners	Zero	Full	Unrestricted	▲	▲
Unit pricing of electricity	Water buyers	High	Full	Unrestricted	▲▲	▲▲▲
Volumetric allocation with unit pricing of electricity/ water	Shareholders of tube well companies	Very high	Rationed	Rationed	▲▲▲▲	▲▲▲▲

Note: ▲ represents a measurable unit of water price and net water productivity in crop production

Table 2: Relation between Irrigation and Gross Returns per Unit Irrigated Area of Wheat for Various Categories of Farmers

Type/ Sample size	Min. to Max./Mean Depth of Irrigation (metre)	Regression Equation
Water Sellers (22)	0.34-1.44/0.78	-730.3Ln(x) + 9708
Water Buyers (12)	0.39-1.59/0.73	1079.7Ln(x) +10114
Shareholders(12)	0.38-0.73/0.60	1316.3Ln(x)+13736

Source: Based on primary data

amongst the three categories of farmers. Though water buyers represent a higher level in the water use regime, the mean value is lower than that of water sellers.

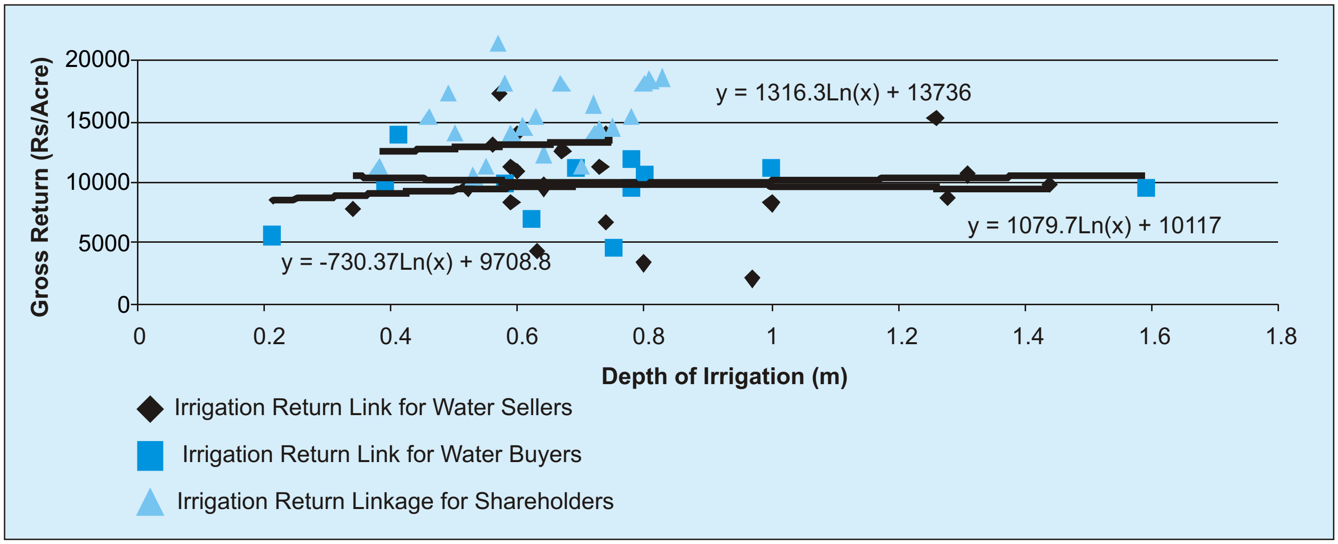
Figure 2 shows the variation in return from crop production per acre across farmers with varying intensities of irrigation. In the case of water sellers, irrigation water application is within a regime where incremental irrigation leads to reduction in gross returns. Therefore, the gross marginal return with respect to irrigation is negative. Irrigation water use by water buyers and shareholders of tubewells is, by and large, within a regime where incremental irrigation leads to increase in gross returns. Hence, gross marginal return with respect to irrigation is positive.

Regression between irrigation water use and gross return from crop production shows that, in the case of water buyers/ sharecroppers and shareholders of tubewell cooperatives, irrigation elasticity of gross return is positive, whereas in the case of water sellers, irrigation elasticity is negative. In the case of water sellers, those who are applying water in larger depths are getting lower returns compared to those who are applying in smaller depths. Needless to say, those who apply in larger depths and get lower yields end up achieving much lower water productivity compared to those who apply water in smaller depths and get higher returns.

High physical efficiency of water use does not mean higher economic returns. Though physical efficiency is higher for water buyers compared to water sellers, the net return is lower because of the high cost of irrigation water.

In case of water buyers, sharecroppers and share holder farmers, those applying more water than others are getting more return from every unit of land, whereas in the case of well owners, the general trend is downward. The regression coefficient is the highest (1316.3) for shareholders, showing that the gross marginal return from every additional unit of irrigation water is highest for them. Therefore if we assume that the level of efficiency with which other resources are used is same across farmers, it could be inferred that shareholders and sharecroppers use water more efficiently than water sellers.

Figure 2: Irrigation vs. Gross Return



Source: Based on primary data

Comparison of Water Productivity in Wheat

Water productivity of wheat for all three categories of farmers was analyzed by comparing the gross return and the irrigation water use figures. Table 3 shows that amongst the three categories, water productivity is highest for shareholders and lowest for water sellers. More importantly, the variation in water productivity across samples is the lowest for shareholders varying from Rs. 4.06 to 8.74 per cubic metre. The difference between the lowest and highest value is Rs. 4.68 whereas in the case of water sellers and water buyers, it is approximately Rs.7. The mean value of water productivity is highest (Rs.5.61/m^3) for shareholders and lowest for water sellers. The difference in the mean value of water productivity between water buyers and water sellers is not very remarkable (Rs. 0.40/m^3). But when we consider the fact that in the case of water purchasers, a good percentage of the water pumped out of the well would be lost during conveyance, actual water productivity would be significantly higher.

However, gross water productivity only reflects the physical efficiency of water use. High physical efficiency of water use does not mean higher economic returns. The net returns that farmers get from every unit of water used depend on how much they pay for water and other inputs. Irrigation cost is the net effect of the water use rate and unit price of irrigation water. Though higher physical efficiency of water use would mean lower water use rate, the overall irrigation cost may not be low as it can be offset by the high unit price for irrigation water. Here, there are significant differences in the cost of irrigation water across water buyers, shareholders, and water sellers. Water buyers pay the highest charges in terms of cost per unit volume of water. The net return per cubic metre of water is the highest for shareholders followed by water sellers and water buyers. Though physical efficiency is higher for water buyers compared to water sellers, the net return is lower because of the high cost of irrigation water.

Comparison of Overall Water Productivity

Potential variations in water productivity across crops (net return per unit volume of water transpired expressed as Rs/ET_0) could be significant even if farmers use water efficiently. For instance, some of the oilseed crops yield much higher return for every unit of water used. In order to get a comprehensive understanding of water use productivity, it is essential to consider water productivity figures for all the crops grown. Farmers were found to be growing castor, mustard, cumin, alfalfa, bajra, jowar, and pioneer jowar in the study area, apart from wheat. Overall water productivity was estimated using the formula:

Overall Water Productivity = Total of gross return from all crops/ Total Volume of Water Used by all Crops

Table 3: Water Productivity of Wheat for Different Categories of Farmers

Farmer Category /(Sample size)	Water Productivity Range (Rs/m^3)	Mean Value of Water Productivity (Rs/m^3)
Water Sellers (22)	0.54-7.51	3.61
Sharecroppers (12)	1.48-8.29	4.01
Shareholders (12)	4.06-8.74	5.61

Source: Based on primary data

Shareholders of partnership tubewells record highest water productivity, followed by water buyers and water sellers. There are two reasons for this phenomenon. First, sharecroppers and shareholders use water very efficiently. Second, sharecroppers and shareholders choose the cropping pattern in such a way that the overall returns (for cubic metre of water) are high.

Overall water use efficiency figures for different categories of farmers are given in Table 4. Shareholders of tubewell partnerships record highest water productivity followed by water buyers and water sellers. There are two reasons for this phenomenon. *First,* sharecroppers and shareholders use water very efficiently. *Second,* sharecroppers and shareholders choose the cropping pattern in such a way that the overall returns (for cubic metre of water) are high. A comparative analysis of the cropping pattern of shareholders, sharecroppers, and water sellers shows that water sellers' cropping pattern is skewed towards water intensive crops like summer jowar and summer bajra, while that of sharecroppers and shareholders is skewed towards cash crops like castor, mustard, and cumin.

The overall gross water productivity (OGWP) figures are higher for water buyers and shareholders compared to well owners who are also engaged in water selling. In order to minimize the effect of probable differences in the level of use of fertilizers, pesticides, and labor on returns, and that of the differences in unit cost of irrigation water on total input costs, net water productivity exclusive of irrigation cost were worked out for all categories of farmers. Here the assumption is that irrigation water application rates are uniform across all categories of farmers.

Values of overall net water productivity (ONWP) exclusive of irrigation cost are presented in Table 5. Water productivity exclusive of irrigation cost is the highest for shareholders of partnership tubewells (Rs. 5.20/m^3), followed by water buyers (Rs. 2.93/m^3) and lowest for well owners (Rs. 2.40/m^3). The effect of improvements in the efficiency of use of water and other inputs on water productivity is quite significant. Now, if one considers the same unit cost of irrigation water across different categories, the differences in net return would only become larger. This is because of the fact that the irrigation water application rates are lower for water buyers and shareholders compared to well owners.

The OGWP figures as estimated above do not capture the price of irrigation water. But price of irrigation water is an important variable

Table 4: Overall Gross Water Productivity for Different Categories of Farmers

Farmer Category /(Sample size)	Overall Water Productivity Range (Rs/m^3)	Mean Value of Water Productivity (Rs/m^3)
Water Sellers (29)	1.21- 8.69	3.61
All Water Buyers (26)	1.21-15.69	5.14
Shareholders of Tubewells (21)	3.24-24.04	6.79

Source: Based on primary data

Table 5: Overall Net Water Productivity for Different Categories of Farmers (Exclusive of Irrigation Cost)

Farmer Category /(Sample size)	Overall Water Productivity Range (Rs/m^3)	Mean Value of Water Productivity (Rs/m^3)
Water Sellers (29)	0.22-6.66	2.40
Water Buyers (26)	-1.44-10.30	2.93
Shareholders of Tubewell (21)	1.59-20.12	5.20

Source: Based on primary data

influencing the overall economic returns from irrigated farming. The total cost of irrigation water—an important deciding factor for net return from irrigated production—is dependent on two important variables: [1] price of irrigation water; and [2] water use rate. Water use rate is determined by the level of efficiency with which farmers use water, which is again influenced by the price of irrigation water.

The ONWP figures are analysed separately for sharecroppers and water buyers. In the case of sharecroppers, price of irrigation water is estimated as the cash equivalent of the crop share given by sharecroppers to water sellers. For water buyers and shareholders of tubewell cooperatives, the cost of irrigation is estimated by taking the total hours of irrigation for each crop and the hourly water charge. In the case of water sellers, irrigation cost is considered as nil.

This is essentially to capture the potential difference in reliability of irrigation between sharecroppers and water buyers, which could result in significant differences in yield levels between these two types of farmers. The ONWP figures for the four categories of farmers are presented in Table 6. The mean value of overall net productivity is the highest for shareholders of tubewell cooperatives. It is the lowest for water buyers and second lowest for sharecroppers. Needless to say, ONWP is very low for water buyers owing to the fact that the cost of irrigation is very high for farmers belonging to this group, while it is much less for shareholders.

Linkage between Volumetric Water Allocation and Cropping Pattern

Well owners grow wheat, bajra, fodder crops, and jowar extensively (wheat 12 percent; bajra 27 percent; jowar 6 percent). Farmers, who buy water, including those who are engaged in sharecropping, grow castor (22.2 percent), wheat (21.6 percent), bajra (18.9 percent), mustard (13.7 percent), jowar (6.9 percent) and cumin (4.3 percent). The cropping system of shareholders is dominated by wheat (36.2 percent) and mustard (36.2 percent).

A strong linkage exists between water pricing and volumetric water allocation and the crops farmers choose to grow in terms of potential water productivity. Well owners, for whom the marginal cost of water is almost zero and who enjoy comparatively much greater access to water, grow crops without much consideration to water productivity. Land use productivity and food security seem to be the most important considerations for them. Their cropping pattern is

Table 6: Overall Net Water Productivity

Farmer Category / (Sample size)	Overall Net Water Productivity Range (Rs/m^3)	Mean Value of Overall Net Water Productivity (Rs/m^3)
Sharecroppers (17)	-0.38-5.74	1.68
Water Buyers (26)	-1.74- 5.74	1.30
Water Sellers (29)	0.22- 5.78	2.40
Shareholders of Tubewells (21)	0.63 -18.65	4.18

Source: Based on primary data

heavily skewed towards bajra (29 percent area under the crop), which has one of the lowest water productivity figures (Rs. 3.67/m^3).

A comparative analysis of the cropping pattern shows that water sellers' cropping pattern is skewed towards water intensive crops, while that of sharecroppers and shareholders is skewed towards cash crops like castor, mustard, and cumin.

Water productivity and water requirement of crops seem to be most important consideration for shareholders. None of them were found to be growing bajra, which has the lowest gross water productivity (Rs. 2.04/m^3) amongst the crops studied and is also most water intensive. Wheat and mustard, which dominate their cropping pattern, have high water productivity (Rs. 5.6/m^3 and Rs. 5.1/m^3 respectively). They also grow crops with very high water productivity such as cluster bean (Rs. 18.4/m^3) and cumin (Rs. 19.9/m^3) in small areas. Again, mustard and cumin are very low water requiring crops. On the other hand, water buyers were found to be putting large area under bajra (18.9 percent), for which they got much lower water productivity compared to mustard (Rs. 2.04/m^3 against Rs. 3.88/m^3), which occupies smaller areas. Also, they were growing cumin in much smaller area, though it is highly water efficient. Thus, water buyers do not seem to attach as much importance to water productivity as shareholders do.

Findings of The Study

The study offers several interesting findings that have major implications for supply and pricing of electricity for agricultural pumping:

Water buyers (under sharecropping arrangement) have higher gross water productivity compared to water sellers through careful use of irrigation water—as reflected in lower water application rates and higher yield rates. This means that physical and agronomic efficiencies in water use improve with positive marginal cost of irrigation water. Further, gross water productivity is further up in the case of shareholders. This means that farmers strive for higher physical and agronomic efficiencies when water is priced on volumetric basis and allocation is rationed.

The overall gross and net water productivity figures exclusive of irrigation cost are the highest for shareholders of partnership tubewells followed by water buyers and well owners who are also water sellers. This means that farmers try to achieve highest economic efficiencies in water use when water is priced on volumetric basis and allocation is rationed.

Water buyers achieve high water productivity mainly through efficiency improvements in water use, and marginally through cropping pattern adjustments. Shareholders achieve high water productivity through shifts in the cropping pattern and efficiency improvements. They select low water requiring crops like mustard, cumin, castor and fennel which yield very high returns for every unit of water used. This corroborates with the model.

Shareholders of partnership tubewells secure higher ONWP compared to well owners. This is in spite of the high expenditure they incur for irrigation.

Net water productivity exclusive of irrigation cost is higher for shareholders (Rs. 5.2/m^3) compared to water buyers (Rs. 2.93/m^3). The difference is because of water allocation norms and reliability of water supply. In the case of shareholders, supply is rationed and known much in advance of the season. Hence, farmers are able to do proper water budgeting. Whereas, farmers who purchase water on hourly basis are at the mercy of well owners. This reinforces the fact that net return from crop production is less elastic to the cost of irrigation than the reliability of irrigation.

Conclusions and Policy Implications

The analysis presented in this paper suggests positive impact of water/electricity price shift, i.e. induced marginal cost of water/electricity on physical efficiency of water use and water and energy productivity in agriculture. Further, the study establishes positive impact of a combination of water/electricity price shifts, i.e. induced marginal cost of water/electricity and water allocation on physical efficiency of water use, cropping patterns and overall water and energy productivity. However, physical efficiency and water and energy productivity impacts are remarkably higher when induced marginal cost coupled with water allocation in which individual entitlements are fixed. Hence, the model is validated.

These findings build a strong case for introducing pricing changes in electricity supplied to the farm sector. A reduction in groundwater and electricity consumption would be achieved if volumetric rationing of energy/water is coupled with induced marginal cost of using energy/water. Water allocation on socioeconomic considerations would automatically take care of equity issues. Proper rationing of groundwater withdrawal along with unit pricing of electricity could, therefore, be an effective tool for achieving efficiency, sustainability and equity.

HEADQUARTERS
127, Sunil Mawatha, Pelawatte, Battaramulla, Sri Lanka
Mailing Address : P. O. Box 2075, Colombo, Sri Lanka
Telephone : +94 11 2787404, 2784080
Fax : +94 11 2786854; E mail : iwmi@cgiar.org

REGIONAL OFFICE FOR SOUTH ASIA
C/o ICRISAT, Patancheru 502324
Andhra Pradesh, India
Telephone : +91 40 30713071
Fax : +91 40 30713074; E mail : iwmi-southasia@cgiar.org

NEW DELHI
South Asia Liaison Office
2nd Floor, NASC Complex, DPS Marg
PUSA Campus, New Delhi 110012, India
Telephone : +91 11 25840811-2
Fax : +91 11 25841294; E mail : b.sharma@cgiar.org

NEPAL
Department of Irrigation, Room # 412 and 413
Jawalkhel, Lalitpur
GPO 8975 EPC 416, Kathmandu, Nepal
Telephone : +977 1 5542306
Fax : +977 1 5536219; E mail : d.pant@cgiar.org

CHINA
Center for Chinese Agricultural Policy
Chinese Academy of Sciences
Building 917, Datun Road, Anwai
Beijing 100101, China
Telephone : +86 10 64889440
Fax : +86 10 64856533; E mail : i.makin@cgiar.org

REGIONAL OFFICE FOR CENTRAL ASIA (Pakistan)
12KM, Multan Road, Chowk Thokar Niaz Baig,
Lahore 53700, Pakistan
Telephone : +92 42 5410050-53
Fax : +92 42 5410054; E mail : iwmi-pak@cgiar.org

REGIONAL OFFICE FOR CENTRAL ASIA (Uzbekistan)
Apartment No. 123
Home No. 6, Murtazaeva Street,
Tashkent 700000, Uzbekistan
Telephone : +998 71 1370445
Fax : +998 71 1370317; E mail : m.hassan@cgiar.org

REGIONAL OFFICE FOR SOUTHEAST ASIA
P. O. Box 1025, Kasetsart University,
Bangkok 10903,Thailand
Telephone : +66 2561 4433
Fax : +66 2561 1230; E mail : iwmi-sea@cgiar.org

REGIONAL OFFICE FOR AFRICA
Private Bag X813, Silverton 0127, Pretoria, South Africa
Telephone : +27 12 845 9100
Fax : +27 12 845 9110; E mail : iwmi-africa@cgiar.org

SUB REGIONAL OFFICE FOR WEST AFRICA
IWMI Ghana, PMB CT 112, Cantonments, Accra, Ghana
Telephone : +233 21 784752-4
Fax : + 233 21 784752; E mail : iwmi-ghana@cgiar.org

IWMI-Tata Water Policy Program

The IWMI-Tata Water Policy Program was launched in 2000 with the support of Sir Ratan Tata Trust, Mumbai. The program presents new perspectives and practical solutions derived from the wealth of research done in India on water resource management. Its objective is to help policy makers at the central, state and local levels address their water challenges – in areas such as sustainable groundwater management, water scarcity, and rural poverty – by translating research findings into practical policy recommendations.

Through this program, IWMI collaborates with a range of partners across India to identify, analyse and document relevant water-management approaches and current practices. These practices are assessed and synthesised for maximum policy impact in the series on Water Policy Research Highlights and IWMI-Tata Comments.

The policy program's website promotes the exchange of knowledge on water-resources management, within the research community and between researchers and policy makers in India.

IWMI-Tata Water Policy Program
Elecon, Anand-Sojitra Road
Vallabh Vidyanagar 388120, Gujarat, India
Telephone: +91 2692 229311-13
Fax : +91 2692 229310
E-mail: iwmi-tata@cgiar.org
Website: http://www.iwmi.org/iwmi-tata

IWMI International Water Management Institute

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