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Farmers' Participation in Informal Groundwater Market in Hard Rock Areas of Peninsular India[§]

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Abstract

This paper has analysed the factors that influence farmers' participation in the informal groundwater market using the Cragg's double hurdle model. For the study, primary data from 171 groundwater farmers belonging to the Eastern Dry Zone of Karnataka were used. The empirical results have shown that agricultural credit and farmers having failed wells positively influence farmers' probability of water buying. With increasing water cost, the farmers are more likely to purchase or sell water and the quantity of water purchased or sold decreases with the increase in irrigation cost. The well-owners who have drip irrigation and land fragments are more likely to sell water. It has been observed that in the study area farmers purchase water at high prices and hence an effective agricultural water pricing is needed. Another option could be to promote joint investment in irrigation which takes care of credit problems and negative externalities of overdraft, resulting in efficient use of resources.

Key words: Cragg's double hurdle model, farmers' participation, water buying, water selling, groundwater markets, Karnataka

JEL Classification: Q00, Q12, C01

Introduction

Buying and selling of the water for irrigation has become a common practice in arid and semi-arid parts of the world. Water markets expanded mainly due to the spontaneous development and expansion of tubewell irrigation. In India, the water markets span

over 15 per cent of its irrigated area (Mukherji, 2004) and are gradually expanding due to increasing water scarcity and rising irrigation costs. It has been reported that out of 82 million farmers, 25.6 per cent (21 millions) owned water extraction mechanisms. Additionally, 24 million farmers have reported renting of irrigation services (Mukherji, 2007). These figures show that about 55 per cent of the farmers are involved in water market in India. These markets have reallocated water from low to higher value uses, encouraged investment in improving the water-use efficiency, and altered water from being a scarce-free resource into an economic resource (Molle *et al.*, 2003).

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Indian water markets are mostly localized, organized by village level informal arrangements and have emerged from the farmers' initiatives. Usually, water is exchanged for crop or cash (Kajisa and Sakurai, 2005). Labour-water transaction is another common form of market transaction. The transaction arrangements are enforced through buyer and seller cooperation. But, water rights in these markets are not explicitly defined (Shah, 1993; Mukherji, 2004; Zekri and Easter, 2007).

In the Eastern Dry Zone (EDZ) of Karnataka (which is located in hard rock area), groundwater markets emerged due to the increasing cost of irrigation, high probability of well failures, low rainfall, low recharge and limited access to other water sources (Manjunatha *et al.*, 2011; Deepak *et al.*, 2005). These water markets provide access to water for resource-poor farmers, who are unable to make investment in a borewell, thereby improve equity in access to the groundwater (Manjunatha *et al.*, 2011; Nagaraj *et al.*, 2005). In addition, water markets have promoted water-use efficiency by allocating this resource to high-value uses (Nagaraj *et al.*, 2005; Deepak *et al.*, 2005; Manjunatha *et al.*, 2011). Therefore, water markets appear to be beneficial for the society in several ways.

In India, the tradition of water buying and selling dates back to the 1970s and the potential benefits from this sharing are well documented in literature (Easter *et al.*, 1999; Brooks and Harris, 2008; Bjornlund, 2003a; Saleth, 1991; Palanisami, 2009; Shah, 1993; Mukherji, 2004; Deepak *et al.*, 2005; Nagaraj *et al.*, 2005; Manjunatha *et al.*, 2011; Sharma and Sharma, 2006; Singh and Singh, 2006). Some authors have also analyzed the factors influencing farmers' participation in water markets (Brooks and Harris, 2008; Bjornlund, 2003b; Saleth, 1991; Sharma and Sharma, 2006; Singh and Singh, 2006).

In this article, farmers' level of participation in water markets has been studied along with the factors that influence their participation. The study is likely to help the policymakers in designing policies to target factors that hinder farmers' participation in the water market.

Data and Methodology

The study was conducted in the Eastern Dry Zone (EDZ) of Karnataka. This region is situated in the hard

rock area of peninsular India. The region is characterized by annual rainfall of 784 mm and has no perennial river (GoK, 2010). In terms of groundwater extraction, the area has been declared as an over-exploited zone by the Department of Mines and Geology, meaning that the extraction of groundwater has exceeded more than 85 per cent of recharge and institutional financing has been completely stopped (GoK, 2010).

Based on the literature review and consultations with the experts from the Karnataka State Departments of Agriculture, Hydrology, and Irrigation, it was found that intense groundwater depletion existed mainly in three out of ten agro-climatic zones of Karnataka. Out of these three zones (Eastern Dry Zone, Central Dry Zone and Northern Dry Zone), agricultural activity was intense in the EDZ and therefore it was selected for the study. This study drew a population of 171 groundwater-dependent farmers spread over three contiguous villages (Patrenahalli, Muthukadahalli and Thandamaradahalli) of the EDZ. Data were collected from these farmers for the agricultural year 2009-10, to study the dynamics of groundwater use. These farmers were sub-classified as: water sellers (27 farmers), water buyers (40 farmers) and self-users (104, farmers who were neither buyers nor sellers).

It was crucial to note that some of the water buyers owned wells, but these did not yield sufficient water and so they were buying water from neighbours. Considering the water discharge, functioning wells and land size, self-users were classified into two sub-categories. One category had the potential to become water sellers and the other category could become water buyers. These sub-categories were termed as potential water sellers and potential water buyers in the study. Among self-users, 70 farmers were identified as potential water buyers and the remaining 34 were identified as potential water sellers. The potential water buyers were those who had one functioning borewell and up to 2,000 gallons per hour (GPH) of water discharge. The reason behind such a consideration was that with 2,000 GPH of water discharge and electricity supply for 8 hours a day from the government for farming activities, they could hardly manage irrigation for 3 acres, irrespective of the type of irrigation method. The average farm-size of the potential water buyers (non-participants) was about 3 acres, and hence they would depend on water sellers if water discharge from

their well declines or the well fails. The potential water sellers had one or more functioning wells with a water discharge of more than 2,000 GPH. It was hypothesized that potential water sellers may not have enough water to the extent of water selling and hence they use water for their own farming. The potential buyers on the other hand, required water to carry out their own farming. It was assumed that changes in economic and resource endowment characteristics due to inadequate rainfall or well failure or non-availability, etc. encourage non-participants to participate in the water market.

From this sample, 70 potential water buyers and 40 water buyers were selected to identify the factors that influence a farmer's water-buying decision and the extent of participation. Further, the data of 34 potential sellers and 27 sellers were used for determining the factors influencing a farmer's water-selling decision and the extent of participation. In the rest of the paper, the terms 'participants' and 'non-participants' in water markets have been used in place of water buyers or water sellers and potential water buyers or potential water sellers, respectively.

Empirical Model

It was found that among the sample farmers, some participated in the water market, i.e. purchased water and some did not, even after having demand. The water buyers also exhibited difference in the quantity of water purchased. Similarly, some of the well-owners sold water to their neighbouring farmers, whereas some did not, even though they had enough water after fulfilling their own requirements. Also, there were differences in the quantity of water sold among water sellers. Based on these observations, the study tried to find answers for the following questions: why some farmers purchase and some do not, and why does the quantity of purchase vary across water buyers? Also, why some farmers sell water and some do not, and why does the quantity of water sold vary across the water sellers?

A Cragg's double hurdle model was used to find answer to these questions. According to this model, a farmer faces two hurdles while deciding whether or not to participate in the water market. In the first hurdle, the decision-maker decides on participation in the water market. The second hurdle is related to the level of participation, i.e. the quantity of water to buy or sell. The most important underlying assumption of the

model is that these two decisions are not made simultaneously, but at two different stages. This also reflects the reality, since at the beginning of a cropping season, a farmer may decide to participate in the water market, even without making perfect plans about the quantity of water to buy or sell. Many factors may influence a farmer's decision afterwards, i.e. water cost, availability of water in the market, drip irrigation, natural rainfall, water requirements for different crops, etc.

The first stage of the Cragg's double hurdle model is a probit model to analyze the factors influencing farmers' participation in the water market, and the second stage is a truncated model for finding the level of farmers' participation in the water market, which was in this case the quantity of water purchased or sold (Cragg, 1971). If d_i^* is the latent variable describing a farmer's decision to participate, y_i^* is the latent variable describing the decision on the quantity of water, d_i and y_i being their observed counterparts. Based on the specification by Cragg (1971) and Moffatt (2005), the two hurdles for a farmer in the water market are:

$$d_i^* = \alpha z_i + v_i \text{ (Participation)} \quad \dots(1)$$

$$y_i^* = \beta x_i + \varepsilon_i \text{ (Extent of Participation)} \quad \dots(2)$$

where,

$$d_i = \begin{cases} 1, & \text{if } d_i^* > 0 \\ 0, & \text{if } d_i^* \leq 0 \end{cases}; \text{ and}$$

$$y_i = \begin{cases} y_i^*, & \text{if } y_i^* > 0 \text{ and } d_i^* > 0 \\ 0, & \text{if otherwise} \end{cases}$$

here, z_i is a vector of variables explaining whether or not a farmer would participate in the water market; x_i is a vector of variables explaining the level of participation; and v_i and ε_i are error-terms.

Two different models were estimated. One was for answering questions related to the demand side, whereas the other was to address supply side questions. The dependent variable in the first stage (a probit model) was a farmer's participation in decision (1 for participating farmers, and 0 for non-participants). In the second stage (truncated regression), the dependent variable was the quantity of water purchased or sold.

Table 1. Summary statistics of variables used in econometric models on a per-farm basis of water buyers

Variables	Potential water buyers (N=70)	Water buyers (N=40)
Dependent variables		
Participation in the water market as water buyer (%)	63.64	36.36
Quantity of water purchased (acre-inches)	-	18.91
Explanatory variables		
Education of farmer (years)	9.00	5.68***
Family size (No.)	5.29	5.05
Farm size (acres)	3.20	1.18***
Dummy for drip irrigation (1=drip user)	0.69	0.48**
Dummy for agricultural credit (1=credit receiver)	0.27	0.58***
Cost of water ^a (₹ /acre-inch)	492.30	705.98**
Net income from dairying (₹)	12659.16	7926.17***
Dummy for non-functioning wells (1=have a non-functioning well)	0.43	0.30

Notes: ^a In the econometric analysis the log of the water cost was used, but here the linear form is reported for easy understanding. Water cost is the amortized irrigation cost for potential water buyers (non-participants) and for water buyers, it is the water rent paid in terms of crop or labour share and/or amortized irrigation cost. The t-test was used to find the statistical significance between potential water buyers and water buyers.

*, **, and *** indicate significance levels at 10 per cent, 5 per cent, and 1 per cent, respectively;

1 acre-inch=102.79 cubic metre

The independent variables for the demand side analysis included: farmer's education (formal years of schooling); family size (number of family members); farm size (acres); dummy for using drip-irrigation technology ('1' for drip users); dummy for agricultural credit ('1' for credit taker); log of per unit of water cost (₹/acre-inch); income from dairy (₹); and dummy of non-functioning wells ('1' if a farmer has a non-functioning well).

The explanatory variables to analyze supply side determinants were: cost per acre-inch of water (₹); functioning wells (number); water discharge rate from a borewell (GPH); log of total own water-use; fragmented parcels (number); ratios of irrigated area to total farm size; log of income from water selling (₹); drip irrigation area to total irrigated area (acres).

According to Carroll *et al.* (2005), Equations (1) and (2) are assumed to be independent, and therefore the error-terms are randomly and independently distributed as: $v_i \sim N(0,1)$ and $\varepsilon_i \sim N(0, \sigma_\varepsilon^2)$. The log-likelihood function of Cragg's model that assumes the probit and truncated regression to be uncorrelated is given as follows:

$$L = \prod_{y_i=0} \left[1 - \Phi(z_i \alpha) \Phi\left(\frac{x_i \beta}{\sigma}\right) \right] \prod_{y_i>0} \Phi(z_i \alpha) \sigma^{-1} \phi\left(\frac{y_i - x_i \beta}{\sigma}\right) \quad \dots(3)$$

where, Φ and ϕ are the standard normal cumulative distribution function and density function, respectively. The log-likelihood function is estimated using the maximum likelihood estimation (MLE) technique.

Results and Discussion

Factors Influencing Water Buying and Level of Buying

Descriptive statistics of the variables used in the econometric analyses are presented in Table 1. The non-participants (potential water buyers) were found more educated and had a larger family and farm sizes than the participants (water buyers). Apparently, they had a better socio-economic position than of the latter. Similar results were observed by Sharma and Sharma (2006), Deepak *et al.* (2005) and Manjunatha *et al.* (2011) in water-scarce regions of India.

The study region is suffering from both physical and economic scarcity of water. Over time, the physical

access to this resource had reduced due to well failures and declining water table and hence farmers were not able to meet all their needs (physical scarcity). Consequently, farmers had to invest more on irrigation to get access to groundwater (economic scarcity). As a coping mechanism to water scarcity, farmers have adopted drip irrigation. Moreover, the state government supports the farmers through subsidies up to 90 per cent of the total cost for adoption of drip irrigation. The impact was reflected in the number of farmers adopting drip irrigation. Among the non-participants, 69 per cent used drip-irrigation technology, whereas among the participants, 48 per cent used the same. The increased adoption by non-participants could be explained by their relatively higher financial status. Water markets had also motivated them towards higher adoption of drip irrigation. It was observed that some water sellers were more willing to sell if a water buyer had drip irrigation since he or she would consume less water but give almost the same water rent as prevalent in the water market. In this way, water market was contributing to the improvement of water-use efficiency.

It was also observed that a higher proportion of non-participants had failed wells. Non-participants use water from their own sources, whereas participants purchase it from water markets. The per-unit cost of water being relatively higher, to the extent of 43 per cent, for participants compared to non-participants. These farmers either paid one-third or one-fourth share of their crops or a varying amount of labor for the procured water from water sellers, depending on the type of crop. Such price differentials were also observed in the studies of Shah (1993), Sharma and Sharma (2006), Deepak *et al.* (2005), Nagaraj *et al.* (2005), Mukherji (2004) in India, by Brooks and Harris (2008) and Bjornlund (2003b) in Australia and by Chong and Sunding (2006) in the United States.

Dairying is one of the major income-generating activities in agriculture. Non-participants receive significantly more income from dairying than participants. This higher income may make non-participants less interested in farming and hence they might cultivate their crops less intensively, using only own water sources. Studies by Singh and Singh (2006) in Uttar Pradesh and Sharma and Sharma (2006) in Rajasthan have found lower probability of water buying at higher non-farm income (which also includes

dairying). The differences between participants and non-participants are significant in all the cases except family size and the dummy for non-functioning wells.

The factors influencing a farmer's decision on water buying decision and level of buying are presented in Table 2. The determinants of participation were identified through the first stage of Cragg's double hurdle model, i.e. probit model. A perusal of Table 2 revealed a negative relationship between education and farmer's decision to purchase water from the market, which implied that educated farmers were less likely to participate in a water market. They also purchased relatively lower quantities of water. This result is consistent with the findings of Singh and Singh (2006) and Sharma and Sharma (2006). We may also argue that more educated farmers are more likely to have off-farm income sources and thus rely less on farm income. These farmers therefore are less likely to invest in agriculture. For the same reason, income from dairying significantly reduces a farmer's probability to participate in a water market. However, for the participants, livestock income positively contributes to the quantity of water purchased. When a farmer with higher income from dairying participates in a water market, it means he buys more water.

The family size has been found to contribute positively and significantly in both stages of the model, implying that a farmer's probability of purchasing water and the quantity of water purchased was higher for households with more number of family members. The exchange of water for labour is a common practice in the study area. The households with a more number of family members are more likely to adopt this practice. Thus, in an indirect way, water markets also help in employment generation. Such labour-water exchange contributed 10.8 per cent to the total income of participants. Similar results were reported by Singh and Singh (2006) in the arid and semi-arid regions of Rajasthan.

The farm size has been found to have a negative impact on a farmer's participation in a water market, but it positively contributed to the quantity of water purchased. The first result indicates a higher dependency on water markets by small farmers, since they are not able to make investment for their own irrigation facility. The investment in irrigation facilities is more likely to be profitable for large-scale farmers

Table 2. Factors that influence water buying and level of buying

Variables	Probit (First stage)	Truncated (Second stage)
	Coefficient (S.E.)	Coefficient (S.E.)
Education of the farmer (years)	-0.448*** (0.139)	-0.051 (0.069)
Family size (No.)	0.243* (0.137)	0.135* (0.070)
Farm size (acres)	-1.284*** (0.333)	0.195* (0.117)
Dummy for drip irrigation (1=drip user)	0.773 (0.555)	-0.046 (0.104)
Dummy for agricultural credit (1=credit receiver)	0.782* (0.434)	-0.010 (0.085)
log of cost of water (₹ / acre-inch)	0.170 (0.435)	-1.118*** (0.170)
Net income from dairy (₹)	-0.0002** (0.0001)	0.001*** (0.000)
Dummy for non-functioning well/s (1 = have non-functioning wells)	0.206 (0.453)	0.253*** (0.102)
Constant	2.208 (2.772)	9.129*** (0.957)

Notes: Dependent variable in the probit: 1 = Participant in a water market as a water buyer; Dependent variable in the truncated regression: log of total quantity of water bought by water buyers;

*, **, and *** indicate significance levels at 10 per cent, 5 per cent, and 1 per cent, respectively; the likelihood ratio test is significant at 1 per cent level

since they have higher water requirements. Hence, large-scale farmers participate less in water markets. But when large farms do not have their own facilities and participate in a water market, they purchase more water than small farms and are even able to bear more cost. Saleth (1991) found a negative and significant relationship between farm-size and water purchasing decision in three states of India (Haryana, Punjab and Uttar Pradesh). He reported that large farmers are mostly borewell owners who are involved in selling water and small farmers are water buyers. Similar results were reported in the studies of Meinen-Dick (1997), Sharma and Sharma (2006), Deepak *et al.* (2005) Nagaraj *et al.* (2005) and Manjunatha *et al.* (2011). In the process, water markets have promoted equity in terms of access to groundwater for small farms.

The study has revealed that farmers with drip irrigation are more likely to participate in the water market, which is contrary to our intuition. But, they are likely to purchase less water from the market. The

insignificant positive relation in the first stage between drip irrigation and the probability of water buying might be due to the fact that water buyers get relatively easy access to water when they have drip irrigation on their farm. Another reason could be that these drip-water buyers consume less water but they pay almost the same rent prevailed in the water market.

Usually, the farmers borrow money from neighbours for investing in agricultural inputs (including water) and irrigation. The dummy of agricultural credit has been found to positively and significantly influence the farmers' probability of participating in a water market and they are less likely to purchase more water.

With rising water costs, the farmers are likely to purchase less water (insignificant relationship), which is in line with our hypothesis. Since the cost of irrigation rises with increasing water cost, farmers purchase less water from the market because it is less profitable for water buyers. This is consistent with the economic

theory which proposes an inverse relationship between water cost (price) and the water-buying decision (demand). But, Saleth (1991) found a positive but insignificant relation between water price and groundwater purchases. This insignificance was attributed to the meagre contribution to total value of yield from irrigation through groundwater purchases, but this was not the case in our study. Water purchases have significantly contributed to the income of participants.

Farmers with non-functioning wells are more likely to participate in the water market and are also likely to purchase more water from the market. These non-functioning wells have contributed to rising cost of water and in such a situation, the water buyers prefer to buy water rather than invest in additional wells, because such investments are risky and huge.

Factors Influencing Water Selling and Level of Selling

The descriptive statistics of the variables used in the econometric analysis are given in Table 3. Among borewell owners, 44.26 per cent sell water to the neighbouring farmers, and the average quantity of water sold is 28 acre-inches. With this quantity, the water buyers are able to meet the requirements of at

least two low water- consuming crops in a season, irrespective of the method of irrigation (drip or furrow). Most participants sold water to the neighbours after meeting their own demand. The participants (water sellers) had a higher number of functioning wells and hence were more involved in water selling activities as compared to non-participants (potential water sellers).

It was also observed that the participants have a higher number of fragmented landholdings, which motivated them to sell water. Further, participants in the water market practice drip irrigation technology more and are able to irrigate with a relatively less quantity of water than used by non-drip users. The drip-users sell the saved water to other farmers. It, therefore shows the positive role of water markets in promoting efficient use of water, not only through reallocation to higher-value uses but also through application of water-saving technologies.

Another contributing factor to water selling might be a relatively low proportion of farmland under irrigation to total farm land of participants, thus showing relatively lower water demand of participants. However, it was not surprising that the quantity of own water-use for irrigation was significantly higher for non-participants than participants in a water market.

Table 3. Summary statistics of variables used in econometric models on per farm basis of water sellers

Variables	Potential water sellers (N=34)	Water sellers (N=27)
Dependent variables		
Participation in a water market (per cent)	55.74	44.26
Quantity of water sold (acre-inches)	-	28.01
Explanatory variables		
Income from water selling ^a (₹)	-	32045.78
Cost per acre-inch of water ^b (₹)	319.84	745.86***
Functioning wells (No.)	1.44	1.63
Water discharge rate from a borewell/s (GPH)	3338.24	3185.19
Drip irrigation area to total irrigated area (acres)	0.60	0.68
Total own water-use ^a (acre-inches)	119.01	72.17***
Fragmented landholdings (No.)	1.32	1.78***
Irrigated area to total farm size	0.52	0.49

Notes: The t-test was used to find the statistical significance between participants and non-participants.

*, **, and *** indicate significance levels at 10 per cent, 5 per cent, and 1 per cent, respectively; GPH= Gallon per hour;

^aIn the econometric analysis the logarithmic form was used, but here the linear form has been reported for easy understanding;

^bWater cost is the irrigation cost estimated through amortized cost technique.

Considering own water-use and sold water, the quantity of water extraction was higher for participants compared to non-participants in a water market.

It was found that the water discharge rate was relatively higher for participants than for non-participants, which might be due to relative efficiency of pumps. This is in line with the results of Singh and Singh (2006) in western Uttar Pradesh. The differences between participants and non-participants in a water market are significant for cost per acre-inch of water, total own water-use and fragmented landholdings. But, the differences are insignificant for the remaining explanatory variables, viz. number of functioning wells, water discharge rate from borewell/s, drip irrigated area to total irrigated area and irrigated area to total farm size.

The factors influencing a farmer's water selling decision and level of buying are presented in Table 4.

The determinants of participation were identified through a probit model. The extent of drip irrigated area to total irrigated area has been found to be positively associated with the water selling decision and negatively associated with the level of participation, i.e. the quantity of water sold. Farmers using drip technology do save more water with efficient water-use and are able to sell water. But, the quantity of water sold reduces as drip irrigated area increases.

The number of fragmented landholdings has depicted a positive sign in the probit model, implying that farmers with more fragmented landholdings are more likely to sell water than farmers with less fragmented landholdings. When a farmer has more fragmented landholdings, it is difficult for him to transport water from one location to the other because of high costs as well as water losses and hence they sell water to the neighbouring farmers. On the other

Table 4. Factors that influence water selling and level of selling

Variables	Probit (First stage)	Truncated (Second stage)
	Coefficient (S.E.)	Coefficient (S.E.)
Cost per acre-inch of water (₹)	0.002 (0.001)	-0.0005*** (0.0002)
Functioning wells (No.)	-0.358 (0.505)	0.269 (0.190)
Water discharge rate from a borewell(s) (GPH)	-0.0001 (0.0003)	-0.001 (0.0001)
log of drip irrigation area to total irrigated area	1.351* (0.798)	-
log of total own water-use	-0.958** (0.522)	-0.015 (0.124)
Fragmented parcels (No.)	1.043*** (0.299)	0.083 (0.103)
Irrigated area to total farm- size	0.878 (1.131)	-0.892*** (0.370)
log of income from water selling (₹)	-	0.421*** (0.082)
Drip irrigation area to total irrigated area (acres)	-	-0.149 (0.229)
Constant	1.432 (2.751)	0.213 (1.180)

Notes: Dependent variable in the probit: 1 = participant in the water market as water seller; Dependent variable in the truncated regression: log of quantity of water sold by water sellers;

*, **, and *** indicate significance levels at 10 per cent, 5 per cent, and 1 per cent, respectively; the likelihood ratio test is significant at the 1 per cent level

hand, a farmer having un-fragmented land will try to irrigate through conveyance pipes and/or mud channels, even if the distance is long. Therefore, policy focussing on reducing land fragmentation through consolidation of landholdings will help in enhancing water-use efficiency.

The cost of water per acre-inch has shown a positive influence on a farmer's decision to sell water and a negative and significant influence on the level of participation (quantity of water sold). It was observed that farmers pumping water from higher depths and having failed-wells sell less water because they do not have enough water surplus. When the cost of water extraction declines, farmers sell more water.

With increasing income from water selling, farmers are more likely to participate in a water market i.e. sell more water. Further, some of them may find it more profitable to sell water than to use it for their own farms. When a farmer uses irrigation on a higher share of his or her own land, he requires more water for the farm and hence sells less water in the market. Singh and Singh (2006) have also found that the size of landholdings, number of land fragments, installed pump capacity and joint-ownership of water extraction equipment are significant and positively associated with a farmer's water selling decision.

Considering first stage of probit estimates, except three variables (number of functioning wells, water discharge rate from borewell/s, and the ratio of irrigated area to the total farm-size), all other variables have depicted the same relationship as was hypothesized. The relationship between these three variables and probability of water selling has been found statistically insignificant.

Concluding Remarks

The study using Cragg's double hurdle model has analyzed the factors that influence farmers' water buying and selling decisions and their level of participation in the water market using farm level data. On the demand side, the estimated results have demonstrated that educated farmers have lower demand for water-purchases from the market. They are less likely to participate in water markets. Farmers with higher income from dairying participate less in water markets, but quantities of water purchased increase with increase in dairy income. Therefore, the government should encourage off-farm activities. The probability

of participation of large farms in a water market has been found less as they are more likely to own a water source. But again, the quantity of water-purchased by the non-participating large farms is more.

The probability of purchasing water and quantity purchased has been found higher for farmers with large families and also for farmers who receive agricultural credit. In rural India, it is difficult to get agricultural credit for small farmers and it is even more difficult in the drought-prone areas since agricultural outcomes are uncertain. Institutional sources are not willing to lend money to small farms because of the requirement of collateral and the risk associated with agriculture. The Indian government could install credit policies to encourage particularly small farms' access to credit, specifically for water-saving technologies. Farmers with non-functioning wells rely more on water markets. With increasing water costs, farmers purchase lower quantities of water.

On the supply side, the estimated results have shown that well-owners who have drip irrigation technology, are more likely to sell water. A significant number of farmers have invested in drip irrigation through their own or borrowed capital, waiting for subsidy from the government. Motivating farmers towards complete adoption of drip irrigation is a task for policymakers. For this, subsidies need to be provided immediately after installation of drip equipment or the government may involve private companies in installation of drip equipment.

The number of fragmented landholdings has depicted a positive influence on well-owners' probability of selling water. Further, well-owners sell more water when they can earn more income from water selling. But the cost of water extraction negatively affects the quantity of water sold. Policymakers should consider reducing irrigation costs through individual well recharge as well as recharge efforts at the community level.

It has been observed that in the study area farmers purchase water at high prices and hence an effective agricultural water pricing is needed. Another option could be to promote joint investment in irrigation which takes care of credit problems and negative externalities of overdraft, resulting in efficient use of resources. The social capital generated by the water market could be used for implementing some of the above mentioned policies.

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References

- Bjornlund, H. (2003a) Efficient water market mechanisms to cope with water scarcity. *International Journal of Water Resources Development*, **19**: 553–567.
- Bjornlund, H. (2003b) Farmers participation in markets for temporary and permanent water in southeastern Australia. *Agricultural Water Management*, **63**: 57–76.
- Brooks, R. and Harris, E. (2008) Efficiency gains from water markets: Empirical analysis of watermove in Australia. *Agricultural Water Management*, **95**: 391–399.
- Carroll, J., McCarthy, S. and Carol, N. (2005) An econometric analysis of charitable donations in the Republic of Ireland. *The Economic and Social Review*, **36**: 229–249.
- Chong, H. and Sunding, D. (2006) Water markets and trading. *Annual Review of Environment and Resources*, **31**: 239–264.
- Cragg, J.G. (1971) Some statistical models for limited dependent variables with application to the demand for durable goods. *Econometrica*, **39**: 829–844.
- Deepak, S.C., Chandrakanth, M.G. and Nagaraj, N. (2005) Groundwater markets and water use efficiency: The case of Karnataka. *IWMI-Tata Water Policy Research Highlight No.12*, Available at <http://purl.umn.edu/43633>
- Easter, K.W., Rosegrant, M.W. and Dinar, A. (1999) Formal and informal markets for water: institutions, performance, and constraints. *World Bank Observer*, **14**: 99–116.
- GoK (Government of Karnataka) (2010) *Karnataka at a Glance*. Department of Economics and Statistics, Bangalore.
- Kajisa, K. and Sakurai, T. (2005) Efficiency and equity in groundwater markets: The case of Madhya Pradesh, India. *Environment and Development Economics*, **10**: 801–819.
- Manjunatha, A.V., Speelman, S., Chandrakanth, M.G. and Van Huylenbroeck, G. (2011) Impact of groundwater markets in India on water use efficiency: A data envelopment analysis approach. *Journal of Environmental Management*, **92**: 2924–2929.
- Meinzen-Dick, R. (1997) Groundwater markets in Pakistan: Participation and productivity. *Research Report-105*, International Food Policy Research Institute, Washington, D.C.
- Moffatt, P.G. (2005) Hurdle models of loan default. *Journal of the Operational Research Society*, **56**: 1063–1071.
- Molle, F., Shah, T. and Barker, R. (2003) The groundswell of pumps: multilevel impacts of a silent revolution. In: *ICID Asian Regional Workshop on Sustainable Development of Water Resources and Management and Operation of Participatory Irrigation Organisations*. 10–12 November, Taipei, Taiwan.
- Mukherji, A. (2004) Groundwater market in Ganga-Meghna-Brahmaputra basin: A review of theory and evidence. *Economic and Political Weekly*, **30**: 3514–3520.
- Mukherji, A. (2007) The energy-irrigation nexus and its impact on groundwater markets in eastern Indo-Gangetic basin: Evidence from West Bengal, India. *Energy Policy*, **35**: 6413–6430.
- Nagaraj, N., Suvarna Kumar, A.H. and Chandrakanth, M.G. (2005) Economic analysis of groundwater markets in central dry zone of Karnataka. *IWMI-Tata Water Policy Research Highlight No.13*, available at <http://purl.umn.edu/53071>
- Palanisami, K. (2009) Water markets as a demand management option: Potentials, problems, and prospects. In: *Promoting Irrigation Demand Management in India: Potentials, Problems, and Prospects*, Eds: R.M. Saleth. International Water Management Institute, pp.47–70.
- Saleth, R.M. (1991) Factors affecting farmers' decision to buy groundwater: empirical evidence from the Indo-Gangetic region. *Indian Journal of Agricultural Economics*, **46**: 349–354.
- Shah, T. (1993) *Groundwater Markets and Irrigation Development: Political Economy and Practical Policy*. Oxford University Press, New Delhi.
- Sharma, P. and Sharma, R.C. (2006) Factors determining farmers' decision for buying irrigation water: Study of groundwater markets in Rajasthan. *Agricultural Economics Research Review*, **19**: 39–56.
- Singh, D.R. and Singh, R.P. (2006) Structure, determinants and efficiency of groundwater markets in western Uttar Pradesh. *Agricultural Economics Research Review*, **19**: 129–144.
- Zekri, S. and Easter, K.W. (2007) Water reforms in developing countries: Management transfers, private operators and water markets. *Water Policy*, **9**: 573–589.