GROUNDWATER IRRIGATION IN HARYANA: INSTITUTIONS AND MARKETS

Proposal for funding

Submitted by
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Summary

This study attempts to analyse the market structure for groundwater transactions in Haryana, and the factors that determine this structure. It focuses on two distinct agro-ecological zones in the state: one with high tubewell density, and one where tubewells are more dispersed, in order to understand the structure and functioning of informal water markets and their impact on overall water use, and allocation of water across farmers. In doing so we will estimate a model of supply that could share some features of well-known models of oligopoly. We will also estimate a water production function, which explicitly accounts for water quality and reliability, to characterise the demand side of the market. Estimation of the model will be followed by simulation exercises to study the effect of policy parameters, such as electricity rates and support prices for crops, on variables of importance, such as water prices and overall water use.

Introduction

Decreasing groundwater tables are posing serious challenges to the sustainability of agriculture in North India. In large part, this is attributable to the increased popularity of paddy (and to a lesser degree sugarcane) cultivation, acreage under which expanded phenomenally in the region since the 1980s. As the scarcity of water becomes increasingly apparent, there is need to shift attention to increasing water productivity, “more crop per drop” as it were.

Clearly, the economic and institutional environment within which farmers operate has significant consequences for the choice of crops cultivated, and for water use. For example, the existence of a credible output price support system, in which the government is committed to purchase (thus far virtually unlimited) grain that is offered to it at the minimum support price, has contributed to the popularity of the paddy and wheat cultivation in this region. The cultivation of the post-monsoon water-intensive paddy crop has also been facilitated by the availability of subsidies for tubewell investments, subsidized diesel and flat-rate electricity prices.

The conventional wisdom cites the lack of appropriate, volumetric pricing of groundwater as the principal reason why farmers continue to sow paddy or sugarcane, both water-intensive crops. Flat rates for electricity imply that there is no incentive to economize on water, both by choice of crop, as well as of cultivation practices. Yet, declining groundwater tables have meant that farmers have had to dig deeper, and invest in more powerful pumps to access groundwater. To the extent that more powerful pumps can be more expensive to run, there is an incentive to economize on the use of water. Second, many of the pumpsets run on diesel, and the cost of pumping water is thus automatically based on volume. That the price of diesel is subsidized clearly influences decisions on whether and how much to pump, but not the fact costs of water through diesel vary directly with the volume of water extracted.

It is now well documented that the scarcity of water at critical stages of plant growth has given rise to informal water markets, in which a variety of pricing and contractual arrangements co-exist. These include both area pricing and interlinking of water contracts with that of other inputs, including labor and credit. Prices vary not only by crop, but also from farmer to farmer, even when the transactions are spot market in nature, suggesting that some monopolistic discrimination may be present. However, it is also observed that because of fragmentation of land holdings, a farmer who sells water in one plot, may also buy water in another plot. There is thus some measure of countervailing power.

While there are a number of studies documenting the existence of informal water markets (see for example the work by Tushaar Shah (1993), Meinzen-Dick (1996)), there are virtually no studies that formally test whether such markets operate efficiently (for an exception see the work of Jacoby et al).

Research Objectives

The first objective of this study therefore is to analyse the structure of water—specifically groundwater—markets in Haryana. The structure of the market determines how prices are formed. This in turn has implications for the quantum of water use and the extent to which the water resource will be depleted. It is well recognized that competitive markets are not necessarily efficient in the presence of externalities--in this case, declining groundwater tables. Indeed, the lower prices implied by competition may themselves exacerbate the depletion of the resource.

In characterising the market for groundwater, tubewell density plays a key role, given that (in this state) water is transported through unlined channels, with attendant seepage and evaporation losses. The potential suppliers of water to a given plot without its own well, are immediate neighbours who own tubewells. It is rare for water to be transported over long distances, or across other farmers' plots. An analysis of the market structure enables us to answer questions such as:

How widespread are local monopolies versus competition? Do competitive structures translate into higher aggregate water use as compared to local monopolies? Do competitive structures supply water more 'reliably' than do monopolies? A priori, our hypothesized answers to these are that: high tubewell density areas are characterised by oligopolistic (as opposed to monopolistic) competition; and that more competitive structures lead to more uniform prices, higher water use, and greater reliability than under monopoly.

A second objective of this study is to quantify the demand for irrigation water for principal crops in the area. In doing so, we not only account for the conjunctive use of canal and ground sources of water, but also attempt to capture various attributes of groundwater, including salinity/sodicity and its timely availability throughout the crop season.

This quantification would enable us to answer questions such as the following: what is the relationship between the imputed willingness to pay for water and the price of electricity/diesel? Our hypothesis is that this differential would be positive; its magnitude would provide a benchmark figure for the extent to which electricity prices may be increased (under unit rate pricing). What is the implicit price of reliability? Of water quality? This exercise will also be used an input in answering the questions raised in the first objective, as we detail later in the methodology section.

The study will focus on two distinct areas in Haryana: one with relatively greater tubewell density, such as that found in the district of Panipat in eastern Haryana, and one with low tubewell density, such as that found in the district of Mahendragarh in the western part of the state. In both areas, water tables have declined over the last two decades.

Literature review

There is a vast literature studying the problems of groundwater, and on water markets in India. A comprehensive review of this literature is beyond the scope of this proposal; the bibliography contains references to some of this work. We summarize below some select contributions.

Dhawan's early work on groundwater degradation systematically classifies degradation arising out of mining of water, and that arising out increasing salinity. He suggests that while decreasing groundwater tables are a cause for concern in many parts of India, the problem may not be as widespread in Haryana and Punjab (his analysis pertains largely to the 1980s), save in a few districts, thanks to the perennial source of recharge afforded by Himalayan snow melt-fed rivers. He also points out that in examining water use by various crops, it is necessary to take soil structure and cultivation practices into account. Thus the puddling of rice in certain types of soils leads to water percolating back into the soil; so that the 'net' water uptake in paddy may not be much higher than say cotton.

Among the pioneering contributions to the analysis of groundwater markets in India is that of Tushaar Shah (1993). In a comprehensive—pan Indian—analysis, his is perhaps the first study to document the various institutional mechanisms through which water sales are transacted. These vary from kind transactions, water contracts interlinked with those for land and/or other inputs, and cash transactions both on a per acre and per volume basis. He observes that while such multiplicity of contract types characterize water markets everywhere, the more 'developed' water markets typically rely on prices that depend on volume, and lease contracts, which follow standardized formats. He characterises water markets in Northern India as being developed. And because of ubiquitous opportunities to buy water, farmers not owning a water extraction mechanism are not necessarily disadvantaged. He also points out that the use of unlined channels to transport water to buyers' fields results in seepage losses as high as 30 to 40 percent. This implies that buyers at some distance from the owner' tubewell face effectively a higher price; another (related) implication is that tubewell owners may act as localized monopolies.

Dubash's analysis of water markets in Gujarat also documents the co-existence of a multiplicity of contracts used for groundwater sales. The type of contract—whether based on a fixed payment per acre, a price per hour, or a share of the crop—varies across village and even across crops. Dubash's analysis is unique in at least two respects; first, he effectively captures the dynamic nature of water contracts, which have changed substantially over time. For instance, in one village, he documents a shift away from share payments to fixed payments, largely in response to difficulties faced by owners in enforcing honest payment, with buyers cheating on the size of the total harvest. Sellers were able to change the terms of the contract 'unilaterally' by exercise of social power; for well owners were typically the large landowners in the village. This had adverse consequences for the reliability of water supplies, which the earlier share system helped ensure. A second significant feature of this study is the salience given to the institutional basis for water contracts. Dubash's analysis highlights the role of social norms in negotiating water contracts; he suggests, for example, that a 'moral' economy operates to prevent sellers from setting anything substantially more than a commonly perceived 'fair' price.

In perhaps one of the few studies of groundwater irrigation in Haryana, Narayan estimates the demand for groundwater for three categories of farmers: owners of electric pumpsets, users of diesel pumpsets, and purchasers of water. Estimating the demand for water as an outcome of a profit maximisation exercise, she employs a switching regression model with different regimes for farmers who are credit constrained, and those who are not. The results suggest that for buyers of water, there is the expected impact of a binding credit constraint on buyers of water, with unconstrained farmers demanding more water than credit-constrained farmers. There is no impact of credit on groundwater demanded by diesel pumpset users; however, credit constrained users of electric pumpsets demand more groundwater relative to unconstrained farmers. Narayan attributes this to the flat rate price of electricity, which implies that the price of water relative to that of other inputs is 'low' so that farmers choose a crop-mix that uses more water, and also attempt to substitute water for other inputs. The principal implication is that greater access to credit would in fact tend to reduce the demand for water used by such farmers.

Jacoby, Murgai and Rehman examine the extent of monopoly power exercised by tubewell owners, and whether they price-discriminate in favour of their tenants, in Pakistan. The framework of analysis used is based on the theory of interlinked contracts, which also predicts that owners of tubewells would use more relative to those who buy from them. Their results find evidence of price discrimination, which is not explained by either spatial characteristics, or any premium paid by any systematic differences in willingness to pay for 'reliable' water supplies. They also find that tubewell owners and their tenants use significantly more groundwater than buyers of groundwater; the combined evidence thus points to misallocation of groundwater resources in this region. A distinctive feature of this paper is that groundwater transactions are treated in an integrated manner with a parallel 'informal market' in canal water that is commonly observed in their study area. Canal water is allocated by turns, and the market operates by the exchange of turns amongst farmers. The main implication of such trading in canal water is that overall water use (including both ground and canal water) may not be allocatively inefficient as indicated by the analysis of groundwater alone.

Methodology

Our approach is to compare market structures in two agro-ecologically distinct regions of Haryana. Although groundwater is used extensively here, tubewell density is not uniform across the state. Areas where the water table is relatively high and the soil is more amenable to cultivation of crops such as paddy, such as along the Western Yamuna Canal (in eastern Haryana), have high tubewell density compared to districts such as Mahendragarh and Hissar, which either have low water tables, or sandy soil or both.

In making this comparison, we exploit the fact that plots that do not have tubewells typically purchase water from immediately neighbouring farms with tubewells. The main reason is that water flows across unlined channels, leading to large seepage and evaporation losses; buying from neighbours greatly restricts these losses. Creating water channels across third party land can also be a problem. As a consequence of this pattern of water transactions, a plot (without a well) which has a single neighbour with a well is effectively purchasing water from a monopoly, whereas a plot with two or more neighbouring farms which have wells can benefit from competition between alternative suppliers. In this latter situation, if the suppliers choose prices without colluding and there are no capacity constraints, we would expect these prices to be close to the marginal cost of water supply; in the monopoly situation, we would expect a higher price and lower quantity of water purchased. Therefore, for a buyer, an important characteristic is whether his plot has one, or many immediate neighbour farms with tubewells.

Even with non colluding alternative suppliers to a plot, we would expect a positive markup over cost if the plot is at a different distance from alternative sources of supply. The presence of transport costs (in the form of evaporation and seepage losses) effectively makes water from alternative sources "differentiated products", and a spatial oligopoly model may then be more relevant. (Such models go back at least to Hotelling. Tirole is a good source for the theory of oligopoly. Empirical work estimating static oligopoly models has become popular in the 1990s; Bresnahan is an early contribution).

The timing of irrigation is important, and we expect a priori that farmers are willing to pay a premium for water at the proper times. This premium may vary with possible correlates such as wealth (ability to pay). If we find evidence of such premia, with a corrresponding "vertical product differentiation" in the sense of water supplied at the desired times/dates for a higher price than water supplied at times other than the desired time, at lower prices, then an oligopoly model that incorporates such "quality" discrimination would be appropriate (Bresnahan estimates a simple vertical product differentiation model using data on automobiles).

We will also identify pairs of well owners who have two way transactions. Due to fragmented holdings, the owner of well A may sell water to the owner of well B, for a plot of B's that is distant from his own well B, and vice-versa. The terms of trade between such well owners do not fall within the ambit of models in which agents are either buyers or sellers, but not both. If such transactions turn out to be significant in our data, then we will incorporate this aspect into our modeling strategy, in order to explain how terms of trade for such transactions are determined, and how they are related to the overall price setting behavior of well owners, and the allocation of water by them. For instance, when it comes to according priority in a queue of buyers who purchase from a particular well, are buyers who also sell water to this well owner accorded some priority, etc.

Critical to the analysis is the buyers' willingness to pay for water. This in turn is dictated by the crop production technology, and level of use of other inputs, including canal water. Thus to address the second objective, we propose to estimate simple production/profit functions; these 'water production functions' would explicitly include the type and timing of irrigation water as inputs. These estimated functions can then be used not only to impute the value of water characteristics such as reliability and quality, but also to obtain farmer-specific or plot-specific willingness to pay, as the value of the marginal product of groundwater on a specific plot.

The fact that some farmers would value reliability of water supplies more than others would imply that markets may be segmented by such differences in willingness to pay. This may for example be the case for buyers located at the tail end of canal water distribution networks. The evidence from groundwater markets in Pakistan Punjab (see Jacoby et al), does not support this; this hypothesis remains to be tested in Haryana.

Empirical estimation of an appropriate structural model, one that is attentive to the above considerations as well as the possibility of social norms in governing water transactions, is the desired goal. The model cannot be spelled out before assessing what factors, of the above ones, are important. Having estimated the model, we can answer questions about (a) the presence and extent of water misallocation, and (b) undertake alternative policy simulations, such as the effect of alternative electricity regimes and support prices on water market prices, water allocation and tubewell density.

Data Requirements:

As noted above, we focus on two separate regions in Haryana, one in the eastern part of the state, where well-density is relatively high, and the second in the drier western region, where well density is low. These areas have been tentatively identified as being in Panipat and Mahendragarh districts, respectively. Although the groundwater table in Panipat is higher than in Mahendragarh, both regions have seen it decline over the years.

Two distinct approaches to the collection of primary data on irrigation have been followed in the literature. Both use stratification: in one case, villages are the primary sampling units, and landholding size is the basis for the second-stage selection. In the other approach, the villages lying around a watercourse constitute the first-stage sampling units, with farmers using a specific irrigation technology constituting the second-stage. Another approach has been to identify sections of a given water course (tail enders, for example), and then to conduct a *census* of all farmers/plots in the area.

In formulating a sampling strategy, it needs to be recognized that much of irrigation in Haryana is conjunctive in nature—involving the use of both canal water as well as groundwater. Canal water allocations follow a warabandi system, where farmers take pre-specified turns in irrigating their fields. Canal water rates are nominal, almost negligible; however, canal water is often unreliable, depending on releases upstream. Inadequate maintenance also results in seepage losses, which has adverse consequences particularly for tailenders. There is evidence however, that the existence of informal groundwater markets has resulted in a more equitable utilization of overall (ground and canal) irrigation water (Vasishtha).

For this reason we focus on sampling villages along a water course. A similar approach has been successfully used by other studies (see for example, Jacoby et al and Vasishtha).

In each district, we will identify a water course, and randomly select a village each at the tail, middle and higher-reaches of the water course. In each selected village, we will obtain a map of all the wells, and identify all plots in which water was either bought or sold. Thus, we will conduct a census of water transactions in each village. This will involve tracking each tubewell from which water was sold, and each plot for which water was purchased. Should the census of water transactions in a given village entail too few observations, we will augment the data set by replicating this procedure in neighbouring villages. Our attempt will be to obtain data on approximately 200 transactions in each watercourse per season.

Also, for each of the villages, we will take the assistance of a geologist to obtain a map of the underlying aquifer. We will also use the revenue records to get the census of plots and wells. In addition, we will employ land use experts to obtain a map of the plots and wells.

The specific kinds of questions we propose to canvass include:

Questions for buyers:

For each transaction:

Desired date of obtaining water
Actual date on which water was provided
Price agreed upon
Price paid
Reason for difference, if any
Volume of water
Extent of mixing with canal water, if any
Distance between tubewell and plot

For each Plot:

History of water purchases—single/multiple sellers -- number of immediate neighbours with wells

Oral record of changes in terms of contract over time

Questions for sellers

Particulars of extraction device
Depth of tubewell
When purchased
When well was deepened, if at all
Costs of extraction
How much water used to irrigate own plot
Quality of water in well (pH, salinity, etc)
To whom water was sold -- number of immediate neighbouring plots without wells

Common questions for buyers and sellers:

Background information

Name of farmer, and age
Names and ages of other members of family
Sources of income other than crop cultivation
Assets: Farm (tractor, tubewell); household

Crop cultivation module

Amount of land owned; leased in; leased out
Number of plots cultivated
By plot:
Crop sown (name of variety)
Seed bought/saved from last harvest. If bought, at what cost

Input use module: for each plot, and by week

Soil type: samples to be taken for laboratory assessment
If plot contains tubewell, sample to be taken twice in crop season for assessing quality
Fertiliser: Amount of fertiliser used;
Cost of fertiliser
Number of applications of fertiliser < / > recommended practice?
Use of manure
Labour use by activity: Number of hours of family labour, men and women
Number of hours of hired labour, men and women
Hired labour payment; hired labour contract type
Tractor hours: Hired and owned; payment for hired tractor use
Pesticide application: quantum and cost
Irrigation: Number of irrigations
Depth of irrigation—canal and tubewell
Irrigation timely? -- Separately for canal and tubewell
If not, how many days after desired date was water availabe?
Quality of water (pH, salinity) for tubewell water.

If farmer is both seller and buyer of water, obtain account of how this influences prices charged, in contrast to situation whether farmer is either buyer or seller, but not both

It is premature to discuss data analysis for objective 1, as this will necessarily be model specific, and model selection will be based on the nature of observations that we record in the field. On objective 2, note that while there are studies documenting the impact of poor quality water, or delayed irrigation, on yields using experimental data from agricultural research stations, comparable assessments based on data from farmers' fields do not exist. In this study, for estimating the technical coefficients of the water production function, we will augment our sample of farmers, to ensure that there are no systematic biases being introduced by focusing only on those farmers who have either bought or sold water. We will therefore randomly sample (stratifying by land-holding size) an additional 100 farmers from our selected villages in each water course. This exercise would also enable us to obtain the implicit prices of quality and reliability of water. The questionnaire administered to these farmers is indicated above.

We hope to simulate through a model the effect of important policy parameters, such as electricity rates and support prices for crops, on variables of importance, such as groundwater levels and choice of crops.

Results and Dissemination

We will disseminate the results of the study in the form of two or more papers in scholarly journals and either an article in a popular journal or a manuscript.

Researchers' Skills

The skills required for this project include the ability to undertake/supervise a primary survey, and to devise economic and econometric models to understand the issues outlined above. Both researchers are economists and have participated in primary surveys earlier.

Revised Time Line.

Nineteen months in all. We propose conduct the survey in the kharif season of 2004, starting June 2004 and ending December 2004. We expect data entry to be completed by March 2005, a first report by September 2005 and the final report by December 2005.

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Financial Information

We propose that the project be housed at the Centre for Development Economics, Delhi School of Economics.

Budget

Two research assistants for 1 year:	Rs. 300,000
Field visits (two districts)	Rs. 100,000
Boarding and lodging in village for one year	Rs. 25,000
Equipment, Stationery, Scientific Input (on Water quality, aquifer map of village etc)	Rs. 100,000
Computing resources and data entry	Rs. 100,000
Dissemination expenses	Rs. 50,000

Centre for Development Economics overheads (approximately 15% of total project cost)	Rs. 95,000
TOTAL	**Rs. 770,000**

Biographical Information

The authors are economics Ph.D.'s from Yale and Cornell Universities respectively. A. Banerji has recently worked on game theory, industrial organization theory and on empirical auctions. J.V. Meenakshi's recent research interests include empirical auctions, food and nutrition, and poverty. Both aucthors have recent experience in conducting primary surveys – their recent work includes collecting and building a detailed data set on grain market auctions in North India. Apart from the two papers using this data that are listed below, another is under consideration at the Journal of Development Economics following a second revision, and two more are in the pipeline.

Brief Biodata

- **A. Banerji**

A. Banerji completed his Ph.D. in economics from Yale University in 1995. He is currently a Senior Lecturer in the Department of Economics, Delhi School of Economics. He has taught courses in Mathematical Economics, Game Theory and Industrial Organization.

Recent Publications

Sequencing strategically: wage negotiations under oligopoly, *International Journal of Industrial Organization*, 2002, 20, 1037-58

Buyer collusion and efficiency of government intervention in wheat markets in northern India: An asymmetric structural auctions analysis, with J.V. Meenakshi, forthcoming in the *American Journal of Agricultural Economics*

Competition and collusion in grain markets: Basmati auctions in north India" with J.V. Meenakshi, forthcoming in Ajitava Raychaudhuri and Biswajit Chatterji, editors, *Growth*, *Finance and Development*

- **J.V. Meenakshi**

J.V. Meenakshi is a Senior Lecturer, Department of Economics, Delhi School of Economics, University of Delhi, where she teaches post-graduate courses in Introductory Econometrics, Agricultural Economics and Applied Demand Analysis. Her research interests include agricultural markets, food demand and nutrient deprivation (selected publications listed below). She has received research grants from the Reserve Bank of India, the Ministry of Agriculture (India), and the World Bank.

EDUCATION:

Ph.D., Cornell University, 1991; Agricultural Economics;

M.S., Cornell University, 1986; Agricultural Economics

EXPERIENCE:

December 1992 - present, Senior lecturer (currently) and Research Associate (earlier**), Delhi School of Economics, University of Delhi**.

November 1991-November 1992, Visiting Scholar, **Centre for Development Studies, Trivandrum, Kerala**.

SELECTED PUBLICATIONS:

On Poverty & Nutrition

"Calorie Deprivation in Rural India: 1983-199/2000" *Economic and Political Weekly*, vol. XXXVIII, no. 4, January 25-31, 2003, with Brinda Vishwanathan

"Impact of Household Size, Family Composition and Socio-Economic Characteristics on Poverty in Rural India" *Journal of Policy Modeling*, vol. 24, 2002, pp. 539-59, with Ranjan Ray

On Agricultural Markets

"Buyer Collusion and Efficiency of Government Intervention in Wheat Markets in Northern India: An Asymmetric Structural Auctions Analysis" Centre for Development Economics Working Paper 104, 2002, with A. Banerji, forthcoming in the *American Journal of Agricultural Economics*

"Competition and Collusion in Grain Markets: Basmati Auctions in North India" Centre for Development Economics Working Paper 91, 2001, with A. Banerji forthcoming in Ajitava Raychaudhuri and Biswajit Chatterji, editors, *Growth Finance and Development*

On Water-related Issues

"Assessing the Impact of the National Watershed Development Project for Rainfed Areas (NWDPRA) on Cereal Production" Report prepared for the Ministry of Agriculture, November 2001.

REFERENCES PROVIDED ON REQUEST