The Impact of Credit on Groundwater Use

– Recent Evidence from India

Tulika A. Narayan
University of Maryland, College Park

First Draft: May 15th, 2002

To be presented at AAEA meetings, Long Beach, CA, 2002

Abstract: An estimate of the impact of credit constraints on groundwater use is obtained from a structural estimation of groundwater demand for Haryana, India. A switching regression model is estimated with separate equations for different groundwater technology types, which yields some interesting results. The farmers who use electric pumps are found to have a positive effect of credit constraints on groundwater use. This implies that with better access to credit, groundwater use would in fact decrease for farmers who are credit constrained. It is argued that this is a result of the electricity-pricing scheme under which farmers pay a flat price for electricity making the per unit price for groundwater very low relative to other inputs. Interestingly, the paper finds evidence that farmers who rely solely on purchased groundwater and therefore who pay full price for groundwater, have a negative impact of credit constraints: farmers who are more likely to be credit constrained demand less groundwater.

JEL Classification: Q17 O13 Q25

I. Introduction

Credit is a critical element in agricultural economy since inputs like seeds and fertilizers are purchased at the beginning of the cultivating season, but returns are realized only at the end of the season. However, formal credit is typically rationed because of information asymmetries and adverse selection that exist in the credit market (Stiglitz and Weiss, 1981; Pender, 1996; Bell, 1988). Furthermore, government imposes interest rate ceilings on formal credit, which also necessitates ceiling (Gonzalez-Vega 1984; Mckinnon 1973; Shaw 1973). When formal credit is rationed typically farmers who have little or no collateral cannot obtain the amount of credit they demand at the going rate of interest. This is because farmers who do not have collateral pose high risk because they do not provide guarantees in case of default and their incentives contribute to a higher default risk. Such farmers may then be compelled to borrow from informal sources like moneylenders and traders who charge high rates of interest. These informal lenders are able to give loans without collateral because these lenders usually have better information about the default risk and ability about their clients. However, they charge high rates of interest to account for the risk that they undertake by giving a loan without collateral guarantee. This implies that in rural areas of developing countries where there are large inequalities in ownership of assets, the asset-poor face binding credit constraints.

When credit is binding the production decisions are not optimal which suggests that improvement in provision of credit should have a direct impact on agricultural productivity. The objective of this paper is to measure the impact of credit on farmers' agricultural decision and in particular to focus on its impact on groundwater use for irrigation. Since groundwater is scarce and water tables are declining (Bhatia, 1992), the effect of credit policy on the depletion of this resource would be critical information for the groundwater resource boards. The common property nature of groundwater extraction in areas where extraction rights are ill defined has led to declining water tables. In the context of India, the semi-arid and arid regions where there is a large dependence on groundwater for irrigation, the problem of declining water tables is particularly critical. Problems of salinity and increasing water extraction costs and the threat of depletion of groundwater resources have increased significantly in such areas.

Since credit can distort input choices and output mix which is directly related with groundwater use, it is expected that groundwater use will be sensitive to changes in improved provision of credit. Furthermore, in the context of Haryana, India, the implications of credit on groundwater use is made interesting in the light of electricity pricing schemes that exist in the state. In Haryana (and in fact several other states in India) for majority of the farmers the cost of electricity for agriculture is fixed per month so that at the margin farmers face only a very low per unit maintenance cost for use of electric pump sets. This implies that the relative price of groundwater with respective to other purchased inputs would be significantly skewed downwards. For farmers who are constrained in the formal credit market and face high rates of interest in the informal sector, the effective cost of purchased would be even higher. This distortion in the relative prices could imply that the farmers may substitute water for other purchased inputs to the extent possible. Farmers for example would choose an output mix that uses more water relative to purchased inputs. This implies that the distortions in input and output choices created by poor access to credit may lead to overuse of groundwater compounding the already existing problem of declining water tables.

As compared to the farmers who use electricity to draw groundwater the farmers who either use diesel pump sets or purchase water and pay the full price for groundwater at the margin, would increase groundwater use with increase in credit. The papers models the choice of irrigation technology and estimates a profit function for each technology type and measure the impact of credit on groundwater use for each of the technology type. Interestingly we find that credit does in fact have a negative impact on the use of groundwater by farmers who use electric pump set and a positive impact on farmers who purchase water.

Previous studies that have looked at credit policies for the agriculture sector have largely ignored its impact on the use of the increasingly scarce and critical resource – ground water. The reason that such an analysis has been difficult is the lack of availability of data. In the data set used in the paper, detailed information on groundwater use is available with data on hours of use of pumps to extract water, which together with information on horsepower and groundwater depth, can be used to calculate the extraction of water. Further, there is information on farmers' estimates of the depth of irrigation and number of irrigations provided on each field, which will provide a second estimate of ground water use.

In what follows in section II details on the data and in the institutional setting are provided, section III presents the theoretical framework of the analysis, in section IV the estimation and results from the groundwater demand estimation are presented and finally in section V the conclusions are presented.

I. Data and Institutional setting.

The data for this study are from a plot level survey of farmers in the state of Haryana, India. Haryana is the smallest state in the country. However, it is one of the most developed as far as agricultural production is concerned. In 1997/98, 36% of the states' gross domestic product was from the agriculture sector. It is also a major supplier of surplus food staples, rice and wheat, to the country. Almost half of its irrigated area depends on groundwater. Thus, groundwater plays an important role in agriculture in Haryana.

The data were collected for 1650 farmers using stratified random sampling for a World Bank power sector reform study. The sample included farmers with different irrigation status – electric pumps users, diesel pump users, canal water users, water purchasers and farmers dependent on rainfall. Sampling of farmers with electric pump sets, was done through a two-stage stratified random sampling procedure, with regions as strata, electricity feeder as primary sampling unit (PSU) and farmers using electric pump sets as secondary sampling units (SSUs). Villages served by selected feeders were completely enumerated and farmers classified according to irrigation status so as to generate lists of SSUs under each category of farmers for each selected feeder. For the selection of farmers using irrigation technologies other than electric pump set, the sampling design used was the two-stage random sampling with the group of villages served by the selected feeders as PSUs and the farmers using a specific irrigation technology as the SSUs.

Information on plot level cultivation was collected for the three seasons – Summer, Kharif and Rabi for the agricultural year 1999 –2000. Detailed information on input use, output and prices was collected along with information on ownership of assets, wells and access to credit. Information on plot level groundwater use was collected each season by asking the farmer the source of irrigation for the plot in a season. The farmers were asked how many times they irrigated the field and the depth of irrigation they gave in each of the irrigations. In addition the farmers were also asked how many hours they ran the pump to draw water. Detailed information on the horsepower of the pump, the depth of the groundwater in the well and type and make of the pump were also asked.

The credit module covered the period five years before the survey year with detailed questions on whether the household was constrained in formal credit. [1] To obtain this information, the farmers were asked if they applied for loans and if so how much they applied for and how much they got. The farmers who did not apply for loans were asked the reasons for not applying. Accordingly, farmers are defined as credit constrained and credit-unconstrained across the two categories of farmers: farmers who applied for a loan and those who did not apply for a loan. Among the category of farmers who applied for a loan, a farmer was defined as credit constrained if they applied for a loan and did not get a loan, or got less than what they had applied for[2]; all other farmers were defined as unconstrained. Of the farmers who applied for a loan, 58% of the farmers were sanctioned loans and of these farmers only 3 farmers reported that the loan amount was not sufficient [3].

---

[1] In this paper the definition of credit constrained and unconstrained farmers refers to constraints in the formal credit market. Even though the questionnaire was designed to cover both informal and formal credit, all the loans reported were from formal sources. Since it highly unlikely that there were no loans taken from informal sector, it is reasonable to conclude the responses pertain to only formal sector.

[2] In addition to a question on the difference between the loan amount sanctioned and the loan amount applied for, farmers were also asked if the loan amount was sufficient. A small percentage of farmers who got the loan amount they applied for stated that the loan amount was not sufficient. These farmers were classified as constrained to allow for the fact that farmers may have applied for a loan amount that they expected to get approved for.

[3] In this paper, marginal farmers are defined as those with less than 1 hectare of land, small farmers with land owned greater than 1 and less than 2 hectares of land, medium farmers with greater than 2 and less than 5 and the large farmers with greater than 5 hectares of land.

The questionnaire also identified farmers who were constrained but did not apply for a loan by asking the reason for not applying. Responses to this query ranged from the farmer not needing a loan to the farmer expecting denial of a loan for lack of collateral. Based on these responses, a farmer was defined as credit unconstrained if the farmer did not apply for a loan because he or she did not need a loan. In the dataset, 57% of farmers who did not apply for a loan reported that they did not need a loan. The remaining 43% of farmers were defined as constrained. The reasons for not applying ranged from lack access to a bank, lack of information about location of the bank, lack of collateral to apply for a loan and high rates of interest. [4] Overall, 43% of farmers reported being credit constrained with the numbers fairly equally divided across different farm size categories-marginal, small, medium and large landowners.

II. Theoretical Framework

The conceptual model is based on farmers who maximize profits, p , subject to a credit constraint. It is assumed that farmers take a loan (credit) in the beginning of the cropping year for the working capital and pay it back with interest after returns are realized. To introduce imperfection in the credit market, the loan amount, S_i, which the i^{th} farmer receives is assumed to depend on the land owned by the farmer, which is an important form

[4] It is debatable whether farmers who did not apply for a loan because of high rates of interest should be classified as credit constrained. From the responses given, it is very clear that the farmers who did not need a loan and farmers who received what they applied for are not credit constrained. Given this, it did not seem appropriate to group these farmers – the credit-unconstrained – with those who did not apply because of high rates of interest. On the other hand, there exists a reasonable argument for these farmers to be classified as credit constrained. Note that the category of farmers who responded that credit was not locally available, are obviously constrained because access to formal credit has high transportation and search costs. To the extent that the high rates of interest faced by farmers may reflect the inability of farmers to seek out lower rates of interest, the argument for classifying such farmers as constrained is similar to that for classifying farmers with no local availability of banks as constrained. However, there can be arguments for including these farmers in the credit unconstrained category. In order to test for the sensitivity of the results of the paper, the regression of interest was run with this alternative criteria for identifying credit constrained farmers, and the results were found to be robust.

of collateral. The loan amount defines the upper bound on what the farmer can spend for consumption requirements, q_i, and working capital.[5] Farmers for whom the loan amount is sufficient to purchase their inputs are defined to be unconstrained and farmers for whom the loan amount is binding are defined to be credit constrained.

Given the endowment of own land V_i, and S_i in the first stage, farmers make their acreage decision, A_i. In the second stage, given the optimal farm size A_i^*, farmers make their decisions on groundwater use, w_i, labor use, N_i and other inputs. In modeling ground water extraction decisions, farmers are assumed to be myopic and therefore it is assumed that they do not account for the effect of their extraction on others or on their future costs of extraction. This assumption would not be far from reality, especially if farmers perceive the aquifer to be too large to be affected by their consumption or if the number of farmers extracting from the aquifer is large.

Farmer's optimization problem

The focus of this paper is on the second stage groundwater use and labor use decision where the acreage, A_i^*, given from the first stage maximization problem. In each year there are three seasons: rabi which is the winter season, summer which is the dry season and kharif which is the wet season. For simplicity in the initial analysis, the input choice will be modeled as a yearly decision. Since we will focus on the water extraction decision

[5] In reality farmers would have some ability to self-finance the working capital, which can be easily incorporated in this formulation by simply deducting the available liquid assets from q_i.

by farmers, in this section the problem is modeled for only those farmers who use groundwater.[6] The profit function is given by

$$\Pi_i(\mathbf{p}, HP_i, X_i, h, r, c, A_i^*, V_i, S_i) =$$

[1a] $$\underset{w_i, N_i}{Max}\, \mathbf{pQ}(w_i, N_i : A_i^*) - (ce(w_i, X_i, HP_i) + hN_i)(1+r)$$
$$s.t$$
$$ce(w_i, X_i) + hN_i + q(A_i^* - V_i) + q_i \le S_i$$

where c denotes the marginal cost of extraction, the function e denotes the relationship between the effort expended in extracting water and the amount of water extracted ($e_w > 0$ and $e_{ww} > 0$), wage rate is denoted by h, q is the rental price of land, X_i denotes the level of water in farmer i's well, HP_i is the horsepower of the pump installed, $\boldsymbol{p}$ is the vector of prices of output, and $\boldsymbol{Q}$ is the multi output production function ($\boldsymbol{Q}_w > 0$, $\boldsymbol{Q}_N > 0$, $\boldsymbol{Q}_{wN} = \boldsymbol{Q}_{Nw} > 0$, $\boldsymbol{Q}_{NN}$, $\boldsymbol{Q}_{ww} < 0$).

Solving the above yields the first order conditions

[1b] $$\boldsymbol{pQ}_w - ce_w(1 + r + l) = 0$$

[1c] $$\boldsymbol{pQ}_N - h(1 + r + l) = 0$$

[1d] $$S_i \ge ce(w, HP_i, X_i) + q(A_i - V_i) + hN_i + q_i\ , \quad l \ge 0$$
$$l - ce(w, HP_i, X_i) + q(A_i - V_i) + hN_i + q_i) = 0.$$

The above yields the optimal labor and water use for farmer i as function of A_i and the parameters of the model. If the credit constraint does not bind then the first order conditions are given by

[1b'] $$\boldsymbol{pQ}_w - ce_w(1 + r) = 0$$

[6] In the estimation, a correction will be made to account for the sample selection bias that will be caused by working with only the ground water users.

[1c'] $\boldsymbol{p}\boldsymbol{Q}_{N}-h(1+r)=0.$

Thus, $w_i^{UC} = w_i(\boldsymbol{p},c,r)$ and $N_i^{UC} = N_i(\boldsymbol{p},h,r)$. Therefore the optimal values of water and labor are independent of the loan amount, $\frac{dw^{UC}}{dS_i}=\frac{dN^{UC}}{dS_i}=0$.

On the other hand if the credit constraint binds then [1d] holds with equality and the first order conditions are given by [1b] and [1c] which yield w_i^C and N_i^C as functions of loan amount. Totally differentiating the first order conditions yields

[2] $$\frac{dw_i^C}{dS_i}=\frac{\boldsymbol{p}h\boldsymbol{Q}_{wN}-ce_w\boldsymbol{Q}_{NN}}{ch\boldsymbol{p}\boldsymbol{Q}_{Nw}-\boldsymbol{p}(ce_w)^2\boldsymbol{Q}_{NN}}>0 \text{ and}$$

[3] $$\frac{dN_i^C}{dS_i}=\frac{\boldsymbol{p}ce_w\boldsymbol{Q}_{wN}-\boldsymbol{p}h\boldsymbol{Q}_{ww}}{ch\boldsymbol{p}\boldsymbol{Q}_{Nw}-\boldsymbol{p}(ce_w)^2\boldsymbol{Q}_{NN}}>0.$$

III. Econometric Structure and Estimation

The theoretical model suggests a switching regression model for groundwater use with separate regressions for farmers who are credit constrained and those who are not. In this estimation a simple representation of the switching regression is modeled wherein only the constant is allowed to change across the two regimes. This simplifying assumption means that the slopes do not change across the two regimes.

Since the objective of the paper is to examine the responsiveness of groundwater use, the estimation is done only for the groundwater users, as a groundwater demand equation does not exist for those who do not use it. The alternative of a regression on the pooled sample of farmers, including those farmers who did not use groundwater, would have been appropriate if it were the case that farmers did not use groundwater because it was optimal for them to do so. In reality, however, groundwater use is characterized by fixed transactions cost. Ownership of wells involves large fixed investment cost in extraction infrastructure and because of poor government services, electricity connections are hard to get. In addition, farmers without pumps, do not necessarily have the option of buying water for several reasons. Firstly, there may not be any willing sellers from the nearby wells and secondly even if there are willing sellers there may be physical constraints to buy water, such as unavailability of transportation canals. This implies that farmers who do not use groundwater maybe rationed out of groundwater usage and therefore it is appropriate to do the regression on only the groundwater users. It is conceivable that farmer characteristics that determine the choice of technology also affect the farmers demand for inputs, which would cause coefficients to be biased in the groundwater demand regression. In order to correct for sample selection bias a technology choice regression is estimated and an equivalent of mills ratio from this polychotomous choice is calculated and used as a regression in the seemingly unrelated regression of input demand and output supply for each of the technology choices.

There are two main groundwater technologies used by the farmers: electric pumps and diesel pumps. Accordingly the farmers can be divided into four mutually exclusive groups. The first group of farmers are those who rely only on an electric pump to irrigate, the second category of farmers are those who rely only on a diesel pump, the third use both and finally the fourth category of farmers are those who do not own any pumps but purchase groundwater from other owners of pumps. In order to analyze the effect of credit constraints on groundwater use, a profit function is estimated for three groups of farmers – the electric pump owners, the diesel pump owners and the non-pump owners. Profit function is not estimated for the fourth category of farmers because of lack of adequate number of farmers in this group.

Drawing from the theoretical framework above, a Generalized Quadratic (GQ) profit function is assumed to carry out the estimation, because it is a flexible functional form and provides a local second order approximation to any arbitrary functional form. The analysis is done on a pooled sample of credit constrained and credit unconstrained farmers with credit measured as a dummy variable. For each groundwater technology, denoted by s, $\{s = 1..3\}$, the second stage maximized normalized profit function, is given by

$$p^{s}(P/P_o \mid z) = \sum_j a_j^s \mathbf{P}_j \big/ P_o + \sum_k \sum_j a_{kj}^s \left(P_k \big/ P_o \; P_j \big/ P_o \right) + \sum_j \sum_k b_{jk}^s \, P_j \big/ P_o \, z_k + \sum_r c_r^s R_r + \sum_j d_j^s C_i \; P_j \big/ P_o + e_i$$

[1.a]

if $\quad e_s < X_i^s a + X_i b^s + h_i^s, \qquad e_s = Max\, I^{*m} - h^s \quad (m = 1..4,\ m \neq s)$ [1.b]

$$I_{is}^{*} = X_i^s a + X_i b^s + h_i^s$$ [1.c]

$$I = s \quad \text{iff} \quad X_i^s a + X_i\, b^s - X_i^m a + X_i\, b^m > h^s - h^m \quad \text{for all } m = 1,..4,\ s \neq m$$

$$C_i^{*} = Z_i\, l + u_i$$ [1.d]

$$C_i = \begin{cases} 1 & \text{if } u_i > -Z_i\, l \\ 0 & \text{otherwise} \end{cases}$$

In the profit function, P_o is the price of the aggregate output bundle, $\mathbf{P}_j$ is a vector of input and prices, $\boldsymbol{z_i}$ is a vector of fixed assets including the installed horsepower of pumps, ownership of bullocks, tractors and machinery, household labor and operable area of land (acreage), *R*, is a vector of control variables which include current rainfall and access to canal. C_i is the dummy variable for credit outcomes and equation [1.d] defined above in chapter II, is the criterion function that determines whether the credit constraint is binding or not.

Equation [1.b] is the technology choice equation so that profit p^s is observed only if s^{th} technology is chosen, that is if equation [1.b] is satisfied. X_i^s is a vector of technology specific variables that vary across farmers which includes the price of the pump, price of the well, and price of water under each technology. The vector of variables X_i are the individual characteristics that do not vary across technology groups and includes the average normal rainfall in the area, covariance of average normal rainfall, groundwater depth, quality of groundwater, availability of canal, ownership of land and other assets, education of the household head, income from other sources, family size, past output prices and wage rate. The distribution function for the error term e_s is given by

$$F_s(e) = \text{Prob}(e < e_s) = \frac{\exp(e)}{\exp(e) + \sum_{j \neq s = 1}^{4} \exp(X_i^s a + X_i b^s)} \quad [2]$$

Since acreage is endogenous to the farmers' decision-making process, predicted acreage should be used in the input demand equations. The instruments for acreage would be past input prices and some measure of supply of demand in the area. These variables were tried but did not prove to be good instruments. In so far as past input prices are concerned these at the outset are not expected to be very good instruments because current prices are highly correlated with past prices. Therefore, in the estimation the observed acreage is used. The coefficient on the acreage variable therefore has to be interpreted with this caveat.

Using Hotelling's Lemma, from a profit function with the above structure, the system of output supply and input demand is given by

$$Q_i^*(P_i / P_o \mid z) = -\left(\sum_i a_i^s \left(\frac{P_i}{P_o} \right) + \sum_k b_{ik}^s z_k + \sum_r c_r^s R + d_i^s C_i + v_i \right)$$

$$Q_i^*(P_i / P_o \mid z) = \left(\sum_i a_i^s \left(\frac{P_i}{P_o} \right) + \sum_k b_{ik}^s z_k + \sum_r c_r^s R + d_i^s C_i + v_i \right)$$

[3.a]

if $e_s < X_i^s a + X_i b^s + h_i^s$, $e_s = Max\, I^{*m} - h^s$ $(m = 1..4, m \neq s)$ [3.b]

$$I_{is}^* = X_i^s a + X_i b^s + h_i^s \quad [3.c]$$

$$I = s \quad \text{iff} \quad X_i^s a + X_i\, b^s - X_i^m a + X_i\, b^m > h^s - h^m \quad \text{for all } m = 1,..4, s \neq m$$

$$C_i^* = Z_i\, l + u_i \quad [3.d]$$

$$C_i = \begin{cases} 1 & \text{if } u_i > -Z_i\, l \\ 0 & \text{otherwise} \end{cases}$$

The input demand and output supply equations given by equations [3.a] are estimated jointly for each of the three technology categories. Three inputs are modeled in the estimation –hired labor, water and an aggregate input that includes pesticides and fertilizers. All the farm outputs are aggregated into one output index to estimate a system of three inputs and one output equation. Over the three seasons the farmers produce a wide variety of outputs ranging from food grains to different types of vegetables and fruits. In the Rabi season a large majority of farmers produce wheat so another method may have been to estimate a system with two outputs –wheat and an aggregate bundle of all other outputs. The results from this method were similar to the ones with one output; therefore the latter was used for simplicity. The aggregate input and output indices are created using the geometric mean price method. The details of this procedure are in appendix 2. All the prices are normalized by the price of the aggregate output so that the output supply equation is dropped from the estimation.

In order to estimate the system of equations in [3] the following procedure is used. In the first stage two estimations are done. Firstly, equation [3.d] is estimated using probit maximum likelihood to get the predicted probability values, $\Phi(\hat{b}Z_i)$. Secondly, the technology choice equation V.3.a is estimated using a multinomial logit. From the first regression the predicted probability $\Phi(\hat{b}Z_i)$ is plugged into equation [3].[7] From the second multinomial logit regression an equivalent of mill ratio is estimated as follows (Maddala, 1994)

$$l^s(X_i^s\hat{a} + X_i\hat{b}^s) = f(\Phi^{-1}(X_i^s\hat{a} + X_i\hat{b}^s))/F^s(X_i^s\hat{a} + X_i\hat{b}^s) \qquad \text{[V.4]}$$

and plugged in equation V.3.a to get an estimable system of input demand equations given by

$$Q_i^*(P_i/P_o \mid z) = -\left(\sum_i a_i^s\left(\frac{P_i}{P_o}\right) + \sum_k b_{ik}^s z_k + \sum_r c_r^s R + d_i^s\Phi(\hat{b}Z_i) + e_i^s + \hat{l}^s v_i\right) \qquad \text{[V.5]}$$

---

[7] The results of the technology choice multinomial logit regression and the probit regression of credit outcomes have not been presented in the paper. The results are available from the author upon request. The credit outcome regression can also be found in Narayan (2002).

An important variable to estimate the groundwater demand equations for the technology options is a measure of the price of water for each of the technology choices. For the water purchasers, the price was reported by the farmers however for the diesel and electric pump owners the price had to be calculated. The calculation of water price for diesel owners is straightforward using the groundwater hydrology literature. However, for the electric pump owners the calculation is somewhat complicated by the fact that only the per unit price faced by the farmer is the marginal cost of maintenance. A production function of water was estimated to get a individual specific estimates of the marginal effort expended in getting one unit of water. The details of this estimation are also not reported in the paper for ease of exposition.

Section IV: Groundwater and Labor Demand Results

Following the procedure mentioned above, output supply and four input demand equations given by equation [3] were estimated. All the prices have been normalized by the price of the aggregate input therefore the output equation was dropped from the estimation. Three input demand equations for groundwater, labor and an aggregate chemical input were estimated for the three technology choices with the equivalent mills ratio as one of the regressor. Symmetry restrictions on the prices were imposed in doing the estimation. The results are reported in Table 1.

The key concern of the analysis is to measure the impact of credit constraints on agricultural production if any, and specifically to focus on its effect on groundwater use. Credit constraint was found to have a significant effect on groundwater use for the water purchasers and the electric pump owners. It did not have a significant effect on groundwater use for the diesel users. As expected, the effect of credit constraint is negative on groundwater use for the water purchaser technology. The greater the likelihood that a farmer is credit constrained the lower the groundwater use controlling for acreage and other fixed assets. Water purchasers pay an hourly price for water used which ranged from Rs 10 to Rs 50 per hour, which made up for a fairly significant percentage of their total cost. The results indicate that the credit constrained farmers use 11 hectare inch less of groundwater per annum. This implies that with better access to credit, in the short run there will be an increase in groundwater use by farmers who rely solely on purchased water.

An interesting result that emerges from the estimation is that the effect of credit constraints on groundwater use by the electric pump owners was found to be *positive*. In other words, the credit-constrained farmers use more groundwater than those who are credit unconstrained. The sign and magnitude of this effect was robust across different specifications. For example in the Generalized Leontief specification, this effect was found to 192.9 and was significant.

In general, it would be the expectation that a credit-constrained farmer would use fewer inputs because of the cash constraint on buying the inputs. As discussed above, for the water purchasers who pay the market price for water, this effect is true. However, the farmers with an electric pump pay a very small marginal price for groundwater. This in turn implies that the relative price of purchased inputs with respect to groundwater would b high so that farmers may substitute cheaper water input with other inputs such as fertilizers and pesticide that are relatively costly. One way that farmers could do this is to choose an output mix that uses more water relative to other purchased inputs. This result is very important in the context of groundwater conservation policies and credit policies. Counter to what one may have expected, greater to access to credit might reduce groundwater usage in the short run for the farmers who rely on electric pumps for irrigation water

The important determinants of groundwater demand for the diesel pump owners were ownership of other farm assets and acreage. The greater the ownership of farm assets, the greater the demand for groundwater. Interestingly the total owned horsepower of the pump did not have any effect on the demand for water, which implies that they were not constrained by the capacity to draw water. Household head's education also had a positive impact on demand for groundwater for this technology category.

For the water purchasers also ownership of farm asset had a positive and significant effect on demand for groundwater. Household labor and acreage also had a positive effect on the demand for groundwater. Interestingly this was the only technology group for whom the current rainfall had an impact on demand for groundwater. The greater the rainfall, the lower the demand for purchased water. Rainfall did not have any significant effect on groundwater demand for electric or diesel pump owners. However, ownership of canal had a significant and negative effect on groundwater use. This is expected, as access to canal would reduce the dependence on groundwater use. Acreage again was an important determinant of groundwater use. The coefficient on acreage needs to be interpreted carefully as there is possible endogeneity bias. Ideally the acreage variable should have been instrumented but none of the possible instruments for acreage worked. The instruments that were tried included past input prices and availability of land in the district. At the outset, past prices are not very good instruments as there usually exists is very high correlation in prices across time. Since the instrumental variables estimation was not feasible, observed acreage was used in place of predicted. The endogeneity bias is expected to be upwards because greater output supply and input use might imply greater cultivated acreage. This implies that the coefficients presented are the upper bound on the effect of acreage on output and inputs.

The regression results in table 2 indicate that credit constraint does not affect farmer's demand for hired labor for electric pump owners. For the diesel users credit was not significant in any of the input demand equations. For the water purchasers however the effect of credit was negative and significant on labor use. The credit constrained farmers used 26 days less of hired labor in a year. At the average wage rate this is a labor cost reduction of Rs 1300 per annum. Credit also had a significant and negative effect on the demand for other inputs for the electric pump owners but not diesel pump owners or water purchasers.

V. Conclusion

A structural estimation of the groundwater demand for three different groundwater use technologies was done. The results indicate that the electricity pricing in Haryana may be encouraging over use of groundwater by the credit constrained farmers who rely solely on electric. This happens because the current electricity pricing creates a distortion in prices for farmers. In contrast, the farmers who pay the full price for groundwater use less water if they are credit constrained. In addition, the analysis suggests that the affect of increased access to credit on groundwater use is complex and may not necessarily mean an increase in groundwater use in the short run. In so far as majority of farmers in Haryana are electric pump owners, it may in fact mean that groundwater use reduces in the short run. The finding however confirms hypothesis that credit constraints have an impact on groundwater use so that changes in credit policy should incorporate this effect.

Reference List

1. Bela Bhatia, “Lush Fields and Parched Throats- A Political Economy of Groundwater in India” *Economic and Political Weekly*. 19, A-142- 170 (1992).

2. Bliss, C.J. and N.H. Stern, “Palanpur: The Economy of an Indian Village. ” New Delhi: Oxford University Press, 1982.

3. Gonzales-Vega, C. "Credit Rationing Behavior of Agricultural Lenders: The Iron Law of Interest Rate Restrictions." *Undermining Rural Development With Cheap Credit.* Editors D. H. Graham and J. D. Von Pischke D.W. Adams, 78-95. Boulder, CO: Westview Press, 1984.

4. Maddala, G. S, “Limited Dependent and Qualitative Variable in Econometrics” 1983.

5. McKinnon, R. *Money and Capital in Economic Development*. Washington, D.C.: The Brookings Institution, 1973.

6. Narayan, T. “*Does Credit Constrain Land Leasing Decisions? –Fresh Evidence from India”*, manuscript, University of Maryland 2002.

7. Shaw, E. S. *Financing Deepening in Economic Development*. New York: Oxford University Press, 1973.

8. Stiglitz, Joe E. and A. Weiss. "Credit Rationing in Markets With Imperfect Information." *American Economic Review* 71, no. 3 (1981): 393-410.

Table 1: Groundwater Demand –Impact of credit and other Assets			
	Electric	**Diesel**	**Water Purchaser**
Credit	232.89**	6.52	-11.38**
	3.09	0.63	-2.91
Gross Area	12.37**	16.48**	2.75**
	14.41	11.20	11.78
Bullocks	-1.14	0.09	0.03
	-1.01	0.12	0.51
Horsepower	-1.12	-2.33	
	-1.00	-1.56	
Household Labor	-5.47**	3.43	0.47**
	-2.13	1.43	2.01
Other Assets	0.06	0.23**	0.04**
	0.85	3.03	3.06
Canal	-73.48**	9.97	
	-2.80	0.82	
Rainfall	0.00	0.01	-0.01**
	0.09	0.36	-6.11
Education	-2.88	41.55*	-0.22
	-0.12	1.93	-0.39
R-Square	0.45	0.79	0.58

Table 2: Labor Demand–Impact of credit and other Assets			
	Electric	**Diesel**	**Water Purchaser**
Credit	35.08	5.42	-26.23**
	1.17	1.40	-2.72
Gross Area	11.13**	8.27**	6.65**
	32.63	15.21	11.53
Bullocks	-0.06	-0.10	0.50
	-0.13	-0.35	3.80
Horsepower	0.63	-1.33**	
	1.41	-2.41	
Household Labor	0.23	0.48	0.80
	0.23	0.54	1.43
Other Assets	0.02	0.05*	-0.01
	0.63	1.73	-0.28
Canal	-48.96**	5.05	
	-4.69	1.12	
Rainfall	0.00	0.01	0.00*
	-0.47	0.85	-1.67
Education	13.93	2.64	0.81
	1.49	0.33	0.57
R-Square	0.81	0.76	0.59

Table 3: Demand for Other Inputs–Impact of credit and other Assets			
	Electric	**Diesel**	**Water Purchaser**
Credit	-9957.52**	751.41	15187.50
	-2.08	1.21	0.64
Gross Area	1074.48**	1604.50**	2122.11
	19.71	18.28	1.52
Bullocks	-7.75	-40.27	405.78
	-0.11	-0.88	1.24
Horsepower	171.17**	102.70	
	2.40	1.15	
Household Labor	9.48	181.25	-817.50
	0.06	1.26	-0.61
Other Assets	19.96**	3.98	-221.77**
	4.75	0.89	-3.11
Canal	-5818.18**	1184.45	
	-3.51	1.62	
Rainfall	-6.74**	0.70	9.51**
	-4.24	0.45	1.71
Education	-1010.44	-121.11	-616.99
	-0.68	-0.09	-0.18
R-Square	0.55	0.79	0.34

Table 4: Price Elasticity			
ELECTRIC PUMP OWNERS			
	Groundwater	**Labor**	**Other Inputs**
Groundwater	-6.35	0.47	-19.40
	-0.87	0.85	-0.88
Labor	0.47	0.32*	-14.61181**
	0.85	1.87	-2.88
Other Inputs	-19.40	-14.61**	1061.95
	-0.88	-2.88	1.09
DIESEL PUMP OWNERS			
	Groundwater	**Labor**	**Other Inputs**
Groundwater	0.22	0.35536**	-14.38038
	-0.87	4.4	-1.45
Labor	0.36**	-0.07	-13.64659**
	4.40	-0.66	-2.88
Other Inputs	-14.38	-13.65**	-217.65
	-1.45	-2.88	-0.26
WATER PURCHASERS			
	Groundwater	**Labor**	**Other Inputs**
Groundwater	0.09**	-0.095437**	0.99058
	2.68	-2.97	1.25
Labor	-0.10**	0.03	-3.87715**
	-2.97	0.39	-2.01
Other Inputs	0.99	-3.88**	-18119.93**
	1.25	-2.01	-3.88