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Comparison of Methods to Economically Valuate Irrigation Water in the Qazvin Irrigation Network (Iran)

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Introduction

Physical availability as well as an adequate allocation of irrigation water are two of the most pressing resource management issues globally. Although water resources are vital for the functioning of any economy, they continue to be depleted and degraded at an unsustainable rate (Birol, et al., 2006). From an economic efficiency perspective, the economic value of irrigation water supplied by public irrigation infrastructure should be a central aspect in water pricing and allocation. Likewise, it is a widespread engineering practice to justify plans for new irrigation infrastructure with cost-benefit analyses (CBA) which, in turn, require data on the economic value of irrigation water. However, the value of water resources is not straightforward to estimate for CBA purposes. This is not only because many of the water resources are public goods in nature, and hence do not have readily available monetary values attached to them, but also because their value is more complex compared to private goods (Birol, et al., 2006, Hanemann, 2006). We report on the results of a comparative study using three different methods to determine the value of irrigation water in the Qazvin irrigation network in northern Iran. Current water fees do, by far, not cover water production costs, not even cover operation costs. A field survey was conducted in 2005–2006 in a part of the Qazvin irrigation network. The value of irrigation water was measured via the contingent valuation method (bidding game), value of marginal product of water and the change in net rent method.We conclude that results differ substantially, and that the net rent probably yielded the most unreliable estimate. Moreover, the effectiveness of the attitudinal questions on contingent valuation answers was checked in accordance to protection motivation theory (PMT) (Rogers and Prentice-Dunn, 1997).

Material and Methods

The value of marginal product (VMP**):** The value of water in agriculture is often estimated by the VMP (Bogges, et al., 1992). Value of marginal product (VMP) of the input (water) reflects the shadow price of the commodity (Young, 2005). Cobb-Douglas and Translog have been used to achieve VMP of household production function: $y = f(L, W, Lab, M, K)$, where y is total value of household production of all planted crops multiplied by their prices plus income from household agricultural machine works for other farmers; L the is total land area possessed or rented by household; W is aggregated amount of water used by each farmer from different resources for different crops; M is index variable for household stock of agricultural machinery

consisting of motorcycle, tractor, combine; *Lab* is potential labour force of the household; *K* is total agricultural credit during 2005 as a proxy of working capital.

Change in net rent (CNR): This method is a development from residual imputation method for approximating value of water, particularly for valuating policies on irrigation of agricultural crops. This model defines the increment in net producer income associated with adding water to a production process as willingness to pay for incremental water (Young and Haveman, 1985). It is the most commonly used method in the ex ante assessment of the irrigation projects. Results of the field survey show that wheat and grain corn can be considered as mutually exclusive crops. By scenario designing, we can move from wheat to grain by more 4000 m^3 of water resources, and as a matter of fact, by change in other inputs. The value of water has been defined as:

$$CNR = [I\ (Grain) - C\ (Grain)] - [I\ (Wheat) - C\ (Wheat)]$$

where *I (Grain)* and *I (Wheat)* are the income that can be achieved by specific level of production of specific crop per hectare and *C (Grain)* and *C (Wheat)* are the production cost of each crop per hectare without considering water costs.

Contingent valuation method (CVM): In CVM studies, the analyst can build the bid function as a result of the utility difference problem which has been solved by respondents. The WTP model is represented by "Constant Only Bid Function Model". Analyst will introduce further parameters into the model in order to reflect the distribution of WTP (Bateman, et al., 2002). Bidding game has been chosen for this study and WTP has been asked for 50 L/s water flow running for 24 hours (4320 m^3) as extra water quota during period of summer. This is the unit quota received from the administration. The simple log-linear WTP function has been used:

$$ln\ (\boldsymbol{WTP}) = \boldsymbol{\beta_0} + \boldsymbol{\beta}\ ln\ (\boldsymbol{X}) + \boldsymbol{e}$$

where X is vector of explanatory variable which is significant (size of household; age of respondent; education level of respondent; ratio of land ownership from second land reform to the total under control land area; weekly assigned water allotment from canal and wells per hectare; and PMT variable which is based on the Likert scale and shows farmers expectation of crop increase by the increase in water resources). These are significant variables from the long list which extracted from questionnaires.

Hypothetical bias and CVM correction by stochastic frontier: Results of different studies show that there is a difference between the hypothetical values or hypothetical bids in CVM surveys and the real values or bids (Hofler and List, 2004). Stochastic frontier (SF) approach can be applied to overcome the hypothetical bias of contingent valuation studies. Using this approach, we can drive the statistical model that can provide an individual bid functions out of hypothetical responses. Then, by calibrating hypothetical bids, we can reveal more real WTP values. According to Hofler and List (2004), If the analyst assumes that the proposed commodity is well defined, but unfamiliar to the respondent, the model output provides a theoretical structure for a systematic overstatement of WTP (Crocker and Shogren, 1991). If the good or commodity is not clearly defined, and the subject has little time to develop a value, then hypothetical bids are systematically less than true values (Hoehn and Randall, 1987). SF, which is proposed by Aigner, Lovell and Schmidt (1977) for production efficiency analysis, can be defined for the bid function as follow:

$$ln\ (\boldsymbol{WTP}) = \boldsymbol{\beta_0} + \boldsymbol{\beta}\ ln\ (\boldsymbol{X}) + \boldsymbol{v} - \boldsymbol{\upsilon}$$

where $\boldsymbol{WTP}$ is hypothetical observed bid, $\boldsymbol{X}$ is vector of person specific bid determining characteristics and $\boldsymbol{\beta}$ is column vector of regressors coefficients. The error term $\boldsymbol{v}$ is assumed to be an independently and identically distributed (iid) random variable with $E(\boldsymbol{v}) = 0$ and $VAR(\boldsymbol{v}) = \boldsymbol{\sigma^2_v}$. The one sided error term $\boldsymbol{\upsilon}$ is assumed to be (iid) exponential or half normal random variable which is independent of $\boldsymbol{v}$. I have tested the direction of the one-sided error term ($\boldsymbol{\upsilon}$) on Qazvin contingent valuation data. As expected, by considering the stated values and indirect valuation results, the correct specification was confirmed to be consistent with the theory of Hoehn and Randall (1987). Therefore, the SF model by negative one-sided error ($\boldsymbol{\upsilon}$) has been considered for

statistical analysis. With estimates of (– υ) available through stochastic frontier by exp(– υ), we are able to calibrate each person's stated WTP.

Study area and data collection: The Qazvin irrigation and drainage network is expanded on the east and west side of Qazvin City at the distance of 170 km on the northwest of the capital Tehran. The network area passes through 80.000 hectare of lands and it is claimed to provide irrigation water for 60.000 hectare of that area partially. The network area covers 88 villages and 30000 farmers. The main canal is 94 km long but secondary and tertiary canals can be as long as 1100 km. Secondary canals are labelled L_1 to L_{20}. The water requirements of the area for agricultural activities are provided from 3 or 4 different sources: canal and official wells (which is under the control of network administration); common wells (which belong to community of farmers in each village) and a few numbers of private wells. An allotment of irrigation water is assigned to each hectare of land of that village from available water from canal system and official wells. Common wells work between 7 to 9 months per year but the canal usually provides water during spring and water does not flow during summer. Official wells work during summer in order to provide water to farmers given the assigned allotments. Canal water allotments are given to farmers in conjunctive-use irrigation system. As the canal system was designed to deliver water volumetrically, irrigator representatives pay money to receive 4320 of water. This value, accounted by 50 L/s water, flows for 24 hours. This measure comes from the size of the gate on the canal and the period in which the main irrigator allows the gates to be open (24 hours). The dependency on the canal water varies throughout the network.

Field Study and Sample Selection: The field survey was conducted during December and January 2005-2006 in the Qazvin network area. By considering attitude and willingness to answer of respondents, as well as accurate metric idea on water and homogeneity on the characteristics of villages, the study area was defined. 10 villages were selected in the middle of L_1, L_2 and L_3 which are homogeneous in the above mentioned characteristics. Stratified two stages random sampling was followed in order to have a representative sample. The area covered by three canals was divided into three strata, and target villages were selected randomly from all villages in each strata. The target respondents were randomly selected from farmers living in villages, but not settlers and non farmers.

Results and Conclusion

Figure1 presents a visual difference between results of different methods. As we can see, all valuation methods ended in higher values than official prices. Additionally, there is a big gap between different valuation results. The significance of one attitudinal variable (expected crop increase by more water) on WTP, presents the possible behavioural reaction to CVM questions in accordance with protection motivation theory (Rogers and Prentice-Dunn, 1997). WTP bids in CVM, which reflects farmers' attitudes toward irrigation water value, can be a main reason for resistance with regards to land unification and application of advance technologies. Under valued WTP bids (and its correction with SF) show that farmers are ready to pay four times more than the official price for water during the period of 2005. Thus, they are willing not to enter into an energy consuming procedure with other members of the community for land unification. Therefore, CVM survey and WTP shows a possibility to encourage land unification and other water saving practices by water pricing policies. A price higher than available offered tariffs near to CVM results can be an encouraging point for discussion amongst farmers on land unification in order to consume water more efficiently. Moreover, the gap between the production function is still available. This gap can be a measure for further correction of pricing policy to provide an incentive for farmers to follow irrigated cropping and not to return to rainfed conditions. The gap between official tariffs and values from all methods can be the main reason for wasteful use of water as a valuable commodity. This low price encouraged conservative approaches toward any change for a more productive use of water. CVM in addition to VMP can be a measure for

correcting pricing policies toward a more useful and efficient use of resources. Furthermore, divergence between the three methods shows the shortages of CNR which must be applied with more cautioun as the main measure for justifying the investment of water resources development projects in benefit-cost analysis.

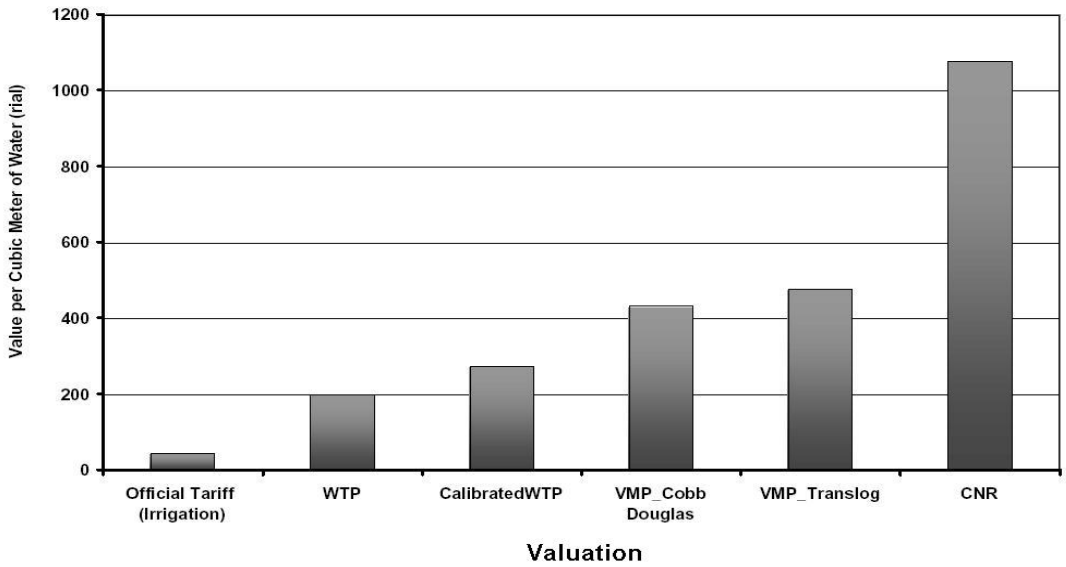

Figure 1: Comparison of value for each m^3 of irrigation water calculated by different methods

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