STRIVER

STRIVER TECHNICAL BRIEF

Strategy and methodology for improved IWRM
- An integrated interdisciplinary assessment in four twinning river basins

TB No. 4

Using choice experiments to value irrigation water

This technical brief discusses an economic valuation method that uses differences in farmers' opinions on water availability scenarios to evaluate their implicit willingness to pay for irrigation water. The method was applied to two irrigation command areas in the Tungabhadra River Basin.

The STRIVER Technical Brief series summarizes results from the EC FP6-funded STRIVER project aimed at an applied research audience and water managers

Using choice experiments to value irrigation water[1]

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Do farmers' willingness to pay for water exceeds current water taxes, and if so under what conditions? We use a valuation method from market research called "choice experiments" to investigate the implicit willingness to pay for different aspects of a hypothetical water pricing regime – increasing the availability of water in the dry season, increasing irrigation frequency, sharing with downstream water users and irrigation pricing. We demonstrate how farmers' current irrigation and cropping practices, location on the canal distributary, participation in water sharing schemes, and membership in water user associations determine their implicit willingness to pay for irrigation water. We also show how farmers choices between hypothetical water pricing regimes can be used to estimate the implicit compensation farmers require to forego water for other downstream water uses, including environmental flows. The fact sheet shows the significance of including the "individual status quo" water practices of farmers who are consistently opposed to new water pricing schemes in choice experiment models. (Photo cover: David N. Barton)

References

This STRIVER Technical Brief is based on the following research reports and scientific literature:

Bateman, I.J., R.T. Carson, B.Day, M. Hanemann, N. Hanely, T. Hett, M. Jones-Lee, G. Loomes, S. Mourato, E. Özdemiroglu, D.W Pearce, R. Sugden, J. Swanson (2002) Economic Valuation with Stated Preference Techniques. A Manual. Department for Transport. Edward Elgar. Cheltenham, UK. 445 pp.

Farmers in irrigation command areas in Karnataka State are required to pay annual "water taxes" whose rates are related to the surface area and type of crop grown. The rates are currently, 400 Rs./acre (sugarcane), 100 Rs/acre (paddy), 60 Rs/acre (Cotton, horticulture, wheat, groundnut, sunflower), 35 Rs/acre (dryland crops such as jowar, maize and spices), 15 Rs/acre (fertilizer crops). Water taxes are collected by the Revenue Department. Non-payment of water taxes can make it difficult for a farmer to conduct financial transactions with the land, such as obtaining loans or selling the title. According to interviews with farmers the water tax is primarily paid in order to have continued access to loans. Although the tax paid is related to whether the crop is dryland or irrigated, the "water tax" is more like a property tax than a water user charge. A challenge of a new water pricing scheme would be to link payment more closely to the volume of irrigation water used. The choice experiment discussed here evaluates a payment linked to each irrigation application, and differentiated by time of season.

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Why choice experiments?

Choice experiments are a new approach to the economic valuation of environmental goods and services that cannot be valued through observation of market prices. While irrigation water can in principle be controlled so that farmers who do not pay for the service are excluded from using irrigation water, the poor irrigation infrastructure and poor regulation means that it is a "non exclusive" resource which is difficult to charge for volumetrically. Choice experiments provide one approach to revealing indirectly what farmers would pay for different levels of water availability, by studying the choices they make between hypothetical levels of supply and water price, as compared to their current situation with often poor supply and lacking payment. Information from CE can be useful for assessing the feasibility of a pricing scheme, and if so, devising differential pricing between areas of different availability. Traditionally choice experiments have been used for valuing improvements in the quality of recreation, for example water qualiity. Hypothetical water quality situations were compared to a status quo situation that was common to all recreational users. For example, all visitors to a site on a river would experience the same quality, which would up to a point not be affected by the number of users ("so called non-rival use").

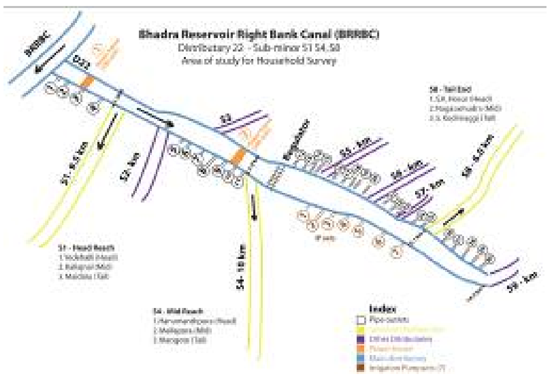

Figure 1 **Distributary 22 – the largest distributary on the Bhadra Reservoir Right Bank Canal**

Because irrigation water is rival in consumption – what economists call a "common pool resource" – every farmer has a different status quo water availability situation depending on where his farm is on the main, distributary and sub-minor canals etc..

In this study we have modified the choice experiment to include information about every farmer's current water availability situation. This information, along with farm and socio-economic characteristics is then used to explain farmers choices regarding a new water availability, sharing and pricing regimes. While the use of "individual status quo" information in a choice experiment is not new to the environmental valuation literature, this is the first time to our knowledge that the approach has been tried on a common pool resource such as irrigation water, and in a setting such as India.

How is it done?

The surveys were conducted in February-March 2008 with interviews of 216 farmers in the Bhadra command area and an equal number in the Tungabhadra command area downstream, for a total sample of 432 households.

Surveys situation. Town located at the middle of S1 – (head-distributary) Basapur, Bhadravati. Photo: Mai Simonsen

Given limited resources we interviewed an equal number of households in the head, middle and tail reaches of the largest distributary in each of the command area. With this sampling strategy we aimed at observing as much variation in water availability, cropping patterns, farm types and socio-economic situation as possible within the time available.

Choice experiments involve asking respondents a number of questions about choices between different policy scenarios, in this case water availability, sharing and pricing scenarios. Unlike the more well-known "contingent valuation" method, which only asks one or two such willingness to pay questions per respondent, choice experiments can often be conducted with smaller sample sizes, while achieving similar accuracy in water valuation estimates. These features attracted the STRIVER project to conduct a comparative test in the Tungabhadra and Tagus basins (reported separately).

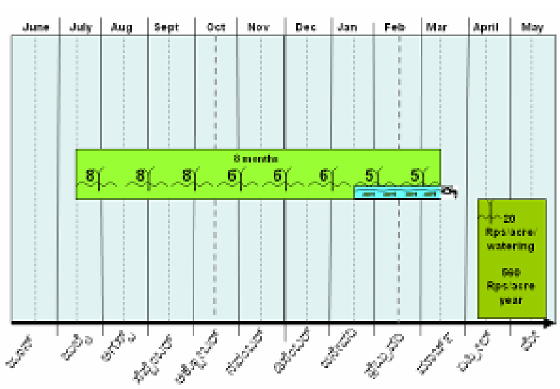

Figure 2 **Example of a scenario for water availability, irrigation frequency, water sharing and irrigation price shown to farmers in the choice experiment**

Figure 3 shows an example of how a water management scenario was presented to the farmers. Farmers were first asked to draw their sowing, watering frequency per month and harvesting periods on a calendar (June-May) such as the one shown. Information was also collected to approximate the volume of a "watering" on the particular farm. This gave us information about the farmer's current water use situation by crop. In the choice experiment, the same calendar background was used to illustrate hypothetical months of water availability in the canal nearest to the farmer was illustrated using a green "bar" with a "crop" icon. This indicated times of year when irrigation could take place. The amount of water available was illustrated by the number of watering per month the farmer would have access to in a water sharing system (locally known as "warabundi"). The concept of water sharing for other needs, particularly for environment (a blue "bar" with fish) and drinking (a "tap" icon) was illustrated in terms of the farmer foregoing one watering per month for these downstream users. Finally, semi-volumetric water pricing was introduced by stating a charge in Rs/acre/watering, and showing the total annual amount in Rs/acre that this would equal given the number of watering in the scenario. In this way the farmer could directly relate the annual water charge to what he was currently paying in annual water tax. The difference in the hypothetical water regime we asked them to consider is that the charge is now proportional to the number of watering, and more directly related to the volume of water used. The height of the green price "bar" was proportional to the charge per watering.

Head end paddy farmers. Tungabhadra Left Bank Canal. Photo: David N. Barton

Farmers were asked to choose between two such scenarios and a third "status quo" situation in which nothing was different from the present. In head end reaches farmers often had more water than what was shown, while in tail end reaches less, and annual water taxes paid were sometimes higher than the totals shown, sometimes less. Six such choice situations were presented to each farmer. Because the scenarios were presented at random, and the amounts of water availability, frequency and sharing designed to be as uncorrelated as possible (so called "orthogonal design"), we can use the choice answers to estimate the significance of each of these aspects of the water regimes for farmers' choices. In particular, we use this choice information to estimate farmers' implicit willingness to pay for water availability, watering frequency and water sharing.

Field canal Bhadra Right Bank Canal.
Photo: Mai Simonsen

There are different ways of analyzing the discrete choices farmers make in a choice experiment. The conditional logit (clogit) model is the "workhorse" that is available in most software packages and rapid to run. It has limitations which can lead to biased parameter estimates. However, because it is fast we used it for a rapid evaluation of the *relative* explanatory power of models using different types of information about the respondents. When estimating implicit willingness to pay and comparing this to current water taxes we wanted unbiased *absolute* estimates and used mixed logit. Mixed logit uses simulation techniques which take longer to run and sometimes do not find a solution for parameter values if the dataset is small relative to the number of attributes being analysed. When this happened we fall back on the clogit model and indicate this as a caution to use of the willingness to pay results.

Heads or tails? Water availability in Tungabhadra

Our sample does not represent the whole of the Bhadra and Tungabhadra command areas, but still reveals some basic differences in water availability. Average water availability in the upstream Bhadra Right Bank Canal (BRBC) is higher than in the downstream Tungabhadra Left Bank Canal (TLBC). Also along the largest distributaries in both areas there was a larger proportion of farms with very low water availability in the TLBC.

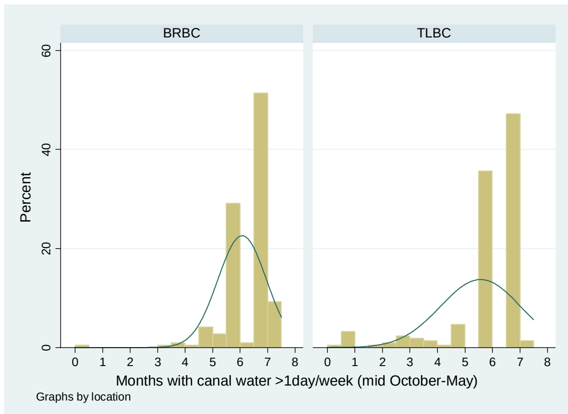

Figure 3 **Months with water in distributary more than 1 day per week in dry season**

Figure 4 looks at water availability in farms close to the head reach of the distributaries versus middle and tail end reaches in both BRBC and TLBC. The same pattern is repeated, with one average one month of available water more in the head end than the tail end, but much wider variation in the tail end than the head end. This means that within the sub-minor canals off the distributary there is also a clear water availability hierarchy. Closer inspection of the data (not shown here) shows the differences between head and tail end farmers' water availability in the dry season is larger in Tungabhadra than in Bhadra.

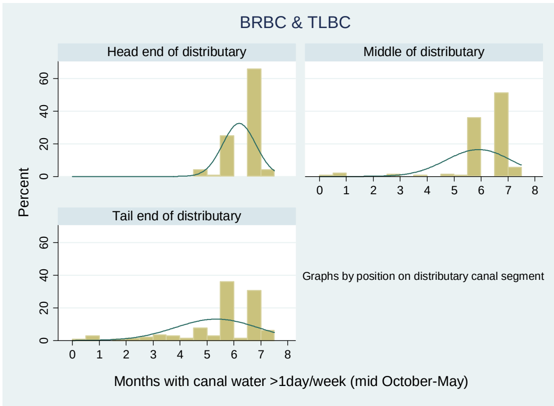

Figure 4 **Water availability head, middle and tail ends of distributaries**

An analysis of farmer characteristics (not shown here) reveal some other significant patterns across the command areas. Farmers who were Water User Association (WUA) members were found significantly more in areas without "warabundi" water sharing arrangements. WUA members where more likely to farm arrica nuts than other types of crops (in the Bhadra command area). WUA members were also significantly more likely to be found in middle reaches of distributaries than in head or tail reaches. An interesting hypothesis is that there is a water availability interval at which farmers percieve the benefits of irrigation organisation to outweigh the costs (Ostrom 1990).

We looked at a number of other farm characteristics simultaneously to find correlations with WUA membership but found no other significant relationships (e.g. total cropping area, land holding, other crop types). Where do farmers themselves say they participate in a "warabundi" water sharing systems? These sharing arrangements were significantly more prevalent in tail end reaches of the distributary than mid or head end reaches. This suggests that WUAs are not a necessary condition for warabundi systems or vice versa. Another interesting characteristics is that farmers in "warabundi" systems were significantly less likely to have paid their water tax since 2007. 197 farmers of a total 432 had no cropped area in the dry season, and 167 had not paid water taxes in 2007.

Village Tungabhadra Left Bank Canal.
Photo: David N. Barton

There is a large variation in the number of irrigations, or actual water use, across the Bhadra and Tungabhadra command areas where we conducted the surveys (Figure 5). The variation in water use across the area we surveyed is striking; 52,6% of farmers irrigated their crops less than two times a month in the sample, while 24,6% irrigated their crops more than 8 times a month in the dry season.

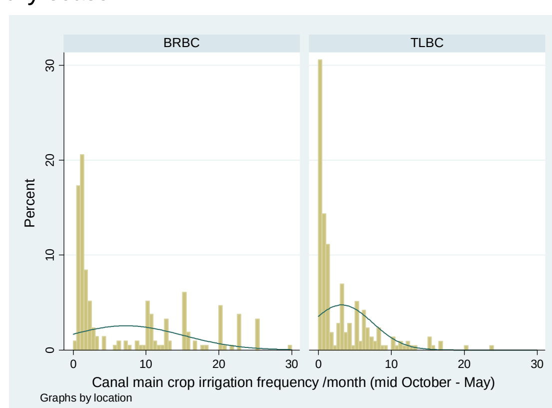

Figure 5 **Number of irrigations per month in dry season in Bhadra and Tungabhadra command areas**

Average number of irrigations is significantly higher in Bhadra. In the Bhadra command area some farmers irrigated crops more than 20 times per month where as this was hardly ever the case in Tungabhadra. Farmers that rely wholly on non-irrigated crops or do not farm in the dry season is more than 30% in Tungabhadra, while less than 20% in Bhadra.

Considering the "status quo" and what should have been paid

A large proportion of farmers preferred the current situation to the alternative water regimes presented in the choice experiments. Accounting for their individual situation in estimating willingness to pay is an important step in understanding the feasibility of new water pricing regimes. Table 1 shows different models that were tested. Model 1 shows the results of a simple model with no consideration of the "status quo" situation of farmers in the survey.

Water regime attributes	Model 1 No status quo information	Model 2 Status quo information, water fee actually paid	Model 3 Status quo information, water fee due given cropping pattern
Water availability	+ + +	+ + +	+ + +
Watering frequency	0	+ + +	+ + +
Water sharing	0	– – –	– – –
Water price	–	0	– – –
No. of observations	1578	7026	4735
Model fit Pseudo R2	0.1549	0.2321	0.3323

Table 1 Conditional logit model fit, sign and significance of attributes (+++/---, +/- , 0 ; 1% , 10% and no significance levels, respectively)

In Model 1 all responses that chose the status quo alternative were excluded from the estimation because they provided no additional information. Model 2 uses information on farmers' current water availability, frequency and *actual* average water tax payment per acre in 2007/2008. This is the model with most information Model 3 is like model 2 except is uses information on what farmers *should have* paid in 2007 had they paid according to actual cropping patterns.

Tail end farmer. Tungabhadra Left Bank Canal. Photo: David N. Barton

We can see that explanatory power of the models improves along with the significance of the water sharing and price attributes. Model 3 uses only information about the farmers, who currently conduct cropping in the dry season (this is the reason for less observations). Nevertheless, the model is superior to the one that also includes farmers who do not crop, nor pay water taxes. Including the group of farmers who do not crop or pay water fees also leads to some important differences in conclusions about WTP.

The value of increasing the irrigation season

The value of the timing of water availability depends on the type of crops planted by the farmer. As the dry season moves into March and April, the importance of canal water for drinking water increases, particularly in the tail end of distributaries.

Figure 6 shows implicit willingness to pay of different subsamples of farmers for an additional month of water available in the farmers' distributary canal. It shows the mean estimate and the 95% confidence interval of willingness to pay implied by farmers' choices between water regimes.

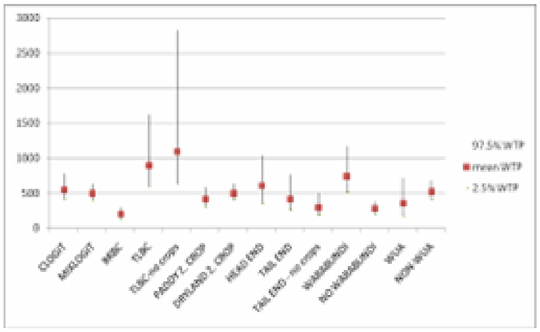

Figure 6 **Implicit WTP for water availability (Rs/additional month)** (Note: estimated using mixlogit model)

Some salient features of the data are that farmers are willing to pay for increasing the irrigation season – an option value of irrigation. There is not a significant difference in the conditional and mixed logit model estimates. Willingness to pay in Tungabhadra is significantly higher than in the upstream Bhadra command area. Farmers living in the tail end of Tungabhadra have a very wide range of implicit benefits of extending the crowing season, reflecting large heterogeneity in farm access to water, even in the tail end. Farmers participating in warabundi water sharing have significantly higher implicit benefits from increased water availability than non-participants. Figure 7 shows that the implicit willingness to pay for water availability in January is significantly lower than in February and March, as the dry season progresses.

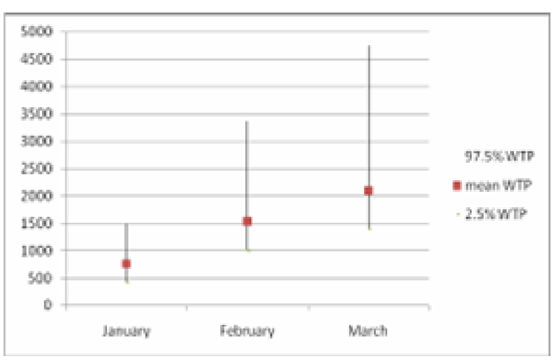

Figure 7 **Implicit WTP for water availability by month(Rs/additional month)** (Note Estimated using Clogit model and farmers who cropped in dry season)

The estimates of implicit willingness to pay for water availability in the dry season is independent of how much water is actually used. In absolute terms it is the most easily comparable of our experimental water regime characteristics to the current water tax. From Figures 6 and 7 we also see that willingness to pay for an extra month of water availability in the dry season is comparable to or considerably higher than the current highest water tax level of 400 Rs/acre year for sugar cane.

Rice fields (paddy fields) in mid-reach village Mallapura, Bhadra Right Bank Canal. Photo: Mai Simonsen

The value of increasing the number of irrigations

The number of irrigations per month is more closely associated with actual water volume used. Although not a direct volumetric estimate it provides an indication of where a volumetric water price may work. Figure 8 shows the implicit willingness to pay estimates for an additional irrigation in different sub-samples of farmers.

Striking features show willingness to pay for additional irrigation being near zero in the Bhadra command area, head end sections of distributaries, and among non-warabundi and WUA member farmers. Conversely, farmers in tail end of distributaries, in the Tungabhadra command area and in warabundi water sharing systems (which are found more in tail end), show an average implicit willingness to pay for an additional irrigation in the dry season that is above 200 Rs/irrigation. This is more than twice the current annual water tax per acre for paddy cultivation.

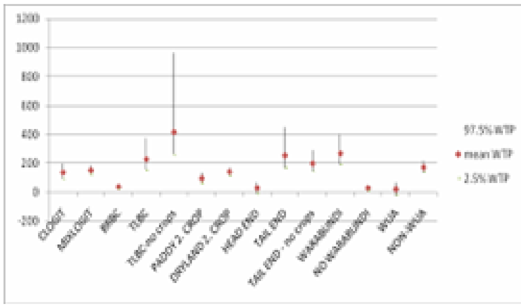

Figure 8 **Implicit WTP for irrigation frequency (Rs/additional irrigation)** (Note: estimated using mixlogit model)

Economists will expect the willingness to pay for water to decline with increasing water use. Figure 8 shows the estimates for different total numbers of irrigations per month. Figure 9 looks at whether implicit willingness to pay for an additional irrigation decreases with the total number of irrigations.

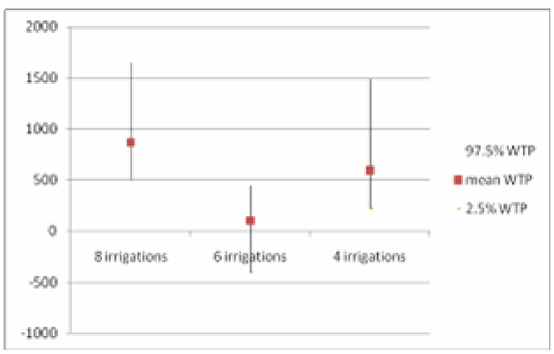

Figure 9 **Implicit incremental WTP (Rs/#irrigations) for water by number of irrigations** (Note: Estimated using Clogit model)

With our data we are not able to show decreasing marginal willingness to pay for increasing water use. The range we looked at in the choice experiment (from 2 to 8 irrigations) was much too narrow compared to the wide variation in irrigations actually taking place (see Figure 5 again). The huge variation in water use makes generalization of conclusions regarding implicit willingness to pay for additional irrigations - across even a single command area such as Tungabhadra – difficult with our data. However, had we done better pilot testing and included the whole range of irrigation frequencies in our definition of water regimes, the choice experiment approach would be well suited to deal with such heterogeneity.

Drinking water Tungabhadra Left Bank Canal. Photo: Mai Simonsen.

The value of water sharing

How do farmers react to a water regime that requires them to reduce irrigation frequency in the dry season for the benefit of downstream drinking water and environmental needs? The choice experiment included some scenarios where irrigation frequency was reduced by one irrigation per month in the last month of available canal water in the dry season. Figure 10 shows the implicit willingness to pay for water sharing.

Water sharing. Tungabhadra Left Bank Canal Photo: Mai Simonsen

The striking features of this data are that forgoing one irrigation per month has a negative implicit willingness to pay for most farmers. But there is large variation also. In the Tungabhadra Left Bank Canal, a share of tail enders who plant no crops in the dry season, a small proportion of participants in warabundi systems, view “forced” water sharing regimes positively.

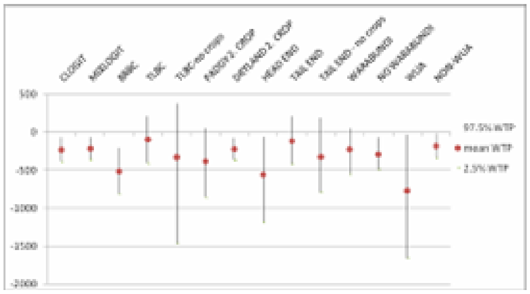

Figure 10 **Implicit compensation needed to share on irrigation with downstream users (Rs irrigation foregone)** (Note: estimated using mixlogit model)

But the *average* tail end farmer in Tungabhadra with no crops is negative to the thought of a regime of sharing with downstream uses (the Tungabhadra river in their case). In the case of the Bhadra command area, head end users in both command areas, non participants of warabundi are all wholly negative to regimes that require sharing.

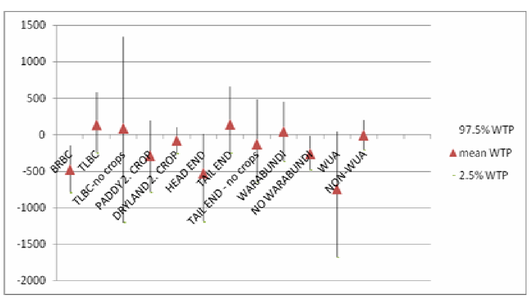

Figure 11 **The difference in implicit willingness to pay between gaining an extra irrigation, or foregoing it for other downstream uses (ΔRs / irrigation)**

Figure 11 shows the difference between implicit willingnes to pay (Figure 8) and the implicit compensation needed (Figure 10) for the respective gain/loss of one irrigation across different groups of farmers. When the difference is negative farmers are valuing a loss of one irrigation more highly than an equivalent gain, as expected by economists if the water really was equivalent. When the difference is positive it shows farmer groups that value losses less than gains. As expected, these are farmers in the tail end of Tungabhadra who do not crop in the dry season for lack of water.

All cubic meters of water are not created equal. Economists expect people with current access to water to value a loss of irrigation more than an equivalent gain, and people without water to do the opposite. While economists call it an “endowment effect”, psychologists call it “loss aversion”. Either way it complicates the volumetric valuation of water.

Conclusions

This technical brief has argued that a choice experiment is an economic valuation method that can be used with success to evaluate the wide differences in water availability, farmer practices and preferences that are found in large irrigation command areas in the Tungabhadra basin. By a detailed accounting of farmers current situation, and how this affects their preferences for hypothetical water regimes and irrigation prices, we can identify how different segments of the farmer population will react to different pricing schemes. We also showed how choice experiments could be used to evaluate the implicit willingness to pay for water in different parts of the dry season and for higher irrigation frequency. Choice experiments can also be used to study welfare losses of water regimes, such as forced water sharing with downstream users and environmental flows, and the implicit compensation farmers would require to accept such policy scenarios.

The Tungabhadra Left Bank Canal. Photo: David N. Barton

The data produced some surprises. Farmers base their choices of water pricing regimes more on what they should have paid, given their cropping pattern, than what they actually did pay in annual water taxes. This reinforces the conclusion that payment of current water taxes has little relation to farmers' water use, or even cropping pattern, responding rather to non-water issues such as farmer financing needs. It underlines the role of so-called "stated preference" valuation methods, and particularly choice experiments, when assessing the feasibility of new water supply and pricing regimes. Another surprise was the characteristic of Water User Association membership. WUA membership were less willingness to pay for water availability and irrigation frequency, and has greater need for compensation for water sharing than non-WUA members. WUA members were also less likely to participate in current "warabundi" water sharing schemes than non-members.

Despite care in design and intensive testing of the survey, the pilot sample was not geographically extensive enough to capture the variation in water use practices across the Bhadra and Tungabhadra basins. The choice experiment did not offer a large enough variation in irrigation frequencies to cover the huge variation seen across the two command areas. Consequently, a large proportion of the farmers in water abundant Bhadra felt the water regimes on offer were too frugal and chose the status quo. The use of a choice experiment models that considered "status quo" characteristics of farmers was therefore crucial.

In terms of methodological improvements to choice experiments, we show that accounting for each farmers' individual status quo situation in the choice models improves the explanatory power of models. Traditionally, valuation practitioners have not used information about respondents who frequently prefer their status quo situation to the hypothetical policies on offer in the choice experiment. We show that this information is valuable. The choice experiment with "individual status quo" information is particularly useful in study settings where (i) one cannot afford to have large sample, (ii) where there is large variation in resource use across respondents, and (iii) the policy so conflictive (water pricing in this case), that one will always expect a significant portion of respondents to prefer their current situation to a proposed policy.

STRIVER

The STRIVER Policy and Technical Brief series translate the results from the project into practical and useful information for policy makers and water managers.

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About STRIVER

STRIVER- Strategy and methodology for improved IWRM - An integrated interdisciplinary assessment in four twinning river basins is a three year EC funded project 2006-2009 under the 6th framework programme (FP6) coordinated jointly by Bioforsk and NIVA. The point of departure for STRIVER is the lack of clear methodologies and problems in operationalisation of Integrated Water Resource Management (IWRM) as pointed out by both the scientific and management communities.13 partners from 9 countries participate as contractual partners in addition to an external advisory board.

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