UNIVERSITIES COUNCIL ON WATER RESOURCES
JOURNAL OF CONTEMPORARY WATER RESEARCH & EDUCATION
ISSUE 131, PAGES 21-25, JUNE 2005

Nonmarket Economic Valuation for Irrigation Water Policy Decisions: Some Methodological Issues

Robert A. Young

Department of Agricultural and Resource Economics, Colorado State University

Nonmarket economic valuation can be defined as the analysis of actual and hypothetical human behavior to derive estimates of the economic value (called accounting or shadow prices) of goods and services in situations where market prices are absent or distorted. Due to the prevailing lack of markets for water-related goods and services, accounting prices are an essential component of economic assessment of public water allocation and other policy choices. Both the theory and methods developed by economists for nonmarket valuation have been greatly expanded and improved over the last several decades, and refinement in the field continues. The progress has occurred with the usual scholarly practice of confronting conceptual models with empirical evidence, and revising the former when it conflicts with the latter.

Most of the effort towards a nonmarket economic valuation has focused on households' valuation of environmental public good uses of water, but producers' uses of water is another important field. For this interdisciplinary audience, my intent here is to discuss some issues regarding nonmarket economic valuation in the context of one of my major professional interests: irrigation water policies (see Young 2005).

Valuation Methods Classified by Quantification Techniques

It will be useful to begin with the point that most applied methods of water valuation fall into one of two broad categories that differ in the basic mathematical procedures and types of data employed in the valuation process. One type, which can be classed as *hypothetico-deductive* methods (henceforth simply *deductive* methods), involves logical processes by an analyst to reason from general premises to particular conclusions. Applied to producers' valuation of water, deductive techniques commence with abstract models of human behavior that are fleshed out with appropriate data to fit the case at hand. In addition to the behavioral postulates (e.g., profit maximization or cost minimization), the data to fit a deductive model will typically include assumptions about the relations between input levels and output (the "production function") plus forecasts of the relevant input and output prices. The accuracy of the results of deductive reasoning depends on the validity of the behavioral and empirical premises, the appropriateness and detail of the model specification and the forecasts of the production function and prices. Examples of deductive techniques applied to valuing water in crop irrigation range from annual cost and return budgeting (via spreadsheets) of single products or an aggregate of multi-product firms to multiperiod mathematical optimization models. Deductive techniques offer the advantage of flexibility. They can be constructed to reflect any desired future policies, economic and technological scenarios, and sensitivities of the results to varying assumptions.

The other broad group of valuation approaches—which I label the *inductive* methods—involve a process of reasoning *from the particular to the general*, or from real-world data to general relationships. Applied to producers' uses, inductive methods involve observation of prices from water rights or land and water rights transactions, responses to survey questionnaires, or from secondary data from government reports. These data are tabulated, and in the more advanced versions, subjected to formal statistical analysis to control for factors other than water that influence production. The accuracy of inductive techniques depends on several factors, including the representativeness and validity of the observational data used in the inference, the set of variables and the functional form used in fitting the data, and the appropriateness of the assumed statistical distribution.

Issue: Conflicts Between Deductive and Inductive Results

A review of the previous literature on economic valuation of irrigation water leads me to conclude that valuations based on observed behavior (inductive techniques) and those based on models of hypothesized farmer decisions (deductive techniques) are often inconsistent. Although my inference is not based on a formal meta-analysis, the large majority of behavior-based (inductive) valuations in the literature appear to show a much lower valuation than do those grounded on the more common deductive models that relied on hypothesized producer actions. A few econometric examples that show results much less optimistic for returns to public irrigation investments than do the deductive analyses commonly used for *ex ante* justification of such investments include: analyses of the contribution of irrigation to farm land values (see Torell et al 1990); studies of regional economic impacts of irrigation in the western US (Cicchetti et al 1975); econometric evaluations of factors (including investments in irrigation infrastructure) affecting regional long term economic growth in India and China (Fan and Hazell 2002); and *ex post* studies of public irrigation water investments in the western US (Wilson 1997). Further evidence is the general inability of governments to collect a significant part of the cost of public irrigation investments.

It is likely that most public investments in irrigation are justified by deductive methods. However, with most applied economists, I share the view that generalizations based on observations of actual behavior (i.e., results of inductive methods) are more realistic and reliable than the results of deductive methods. Although inductive methods continue to require improvement and reformulation, when inductive methods yield different predictions than deductive methods, it will be useful to consider whether and how the deductive methods should be altered and revised. A finding of systematic bias would suggest a need for refinement in deductive irrigation water valuation for accounting prices to be more reliable as guides to investing in or allocating irrigation water supplies in the future.

Conceptual Framework for Valuation of Producers' Goods

To analyze the issue of inductive versus deductive approaches, begin with a conceptual framework grounded in production theory. Consider a multi-crop production function that expresses the maximum expected outputs of a set of crops associated with a package of known inputs: $Y = f(X_M, X_H, X_K, X_L, W)$, where Y refers to the quantities of outputs, and X to the quantities of various non-water inputs, and W is irrigation water. The subscripts refer to groups of inputs where materials, energy and equipment is M; human effort (e.g. labor, supervision) is H; capital is K; nonirrigated land is L. The production function can apply to a single farm, or to broader geographical areas, such as a region.

Both inductive and deductive approaches proceed from the production function to a measure of the value of irrigation water. Inductive methods employ observational data and statistical (usually regression) methods to fit a production function, from which can be derived the input demand function for irrigation water, the producers' willingness to pay for alternative amounts of irrigation water.

The most common deductive method applied to irrigation water valuation is called the *residual method*, which assumes optimizing producers who can forecast the production function and prices of outputs and inputs other than water. The economic value of the unpriced scarce input (irrigation water) is derived as the net return to water; the expected revenues minus the expected non-water costs or per unit land area (e.g., acre). For a single crop for one year, this net return (denoted R_{W1}) represents the willingness to pay per acre for water delivered to the farm gate:

$$R_{W1} = YP_Y - (P_M X_M + P_H X_H + P_K X_K + P_L X_L) \quad (1)$$

All estimated nonwater costs of production are deducted from expected revenues (for if they were not, the residual would be correspondingly overestimated). The net return to water per acre is usually divided by the acre feet of water delivered or consumed per acre to obtain an estimate of the unit value of water (e.g., $/acre foot). Water demand functions derived via more rigorous methods (mathematical optimization models) are also classified as deductive analyses.

Different Concepts of Irrigation Water Value

A significant premise is that there is *no single "economic value" of water*. Non-market economic valuation measures the net benefit (welfare change) associated with some policy-induced change in the attributes of the good or service. Thus, there are a number of benefit concepts, each applicable in specific decision contexts. To select the appropriate concept for measurement, it is important to clarify the specific attributes of the situation and decision in question.

It is worthwhile to differentiate between *at-site* and *at-source* value estimates. As with any economic commodity, the willingness of a user to pay for water depends on the place, form, and time for which the estimate is made. An at-site value refers to the value at the farm receiving point (headgate or wellhead). The at-source value, in contrast, refers to the value in the natural hydrologic system, at the point of withdrawal. Water for irrigation must be captured and transported from the point in a natural watercourse to the place of use. Thus, value at site will exceed that at the source by the costs of transportation and storage, which can be expressed by subtracting acquisition or pumping costs from the net return in equation (1). Letting D represent the costs of delivery, an at-source value (R_{W2}) can be expressed as:

$$R_{W2} = R_{W1} - D \qquad (2)$$

Since the value estimates need to be comparable across sectors, and because in-stream values are at-source, at-source estimates are most appropriate for studies of intersectoral water allocation.

Because policy decisions relating to water entail a range of cases, from major long-lived capital investments to one-off allocations in the face of immediate events such as droughts, it is important to distinguish carefully between *long run* and *short run* values of irrigation water. The distinction relates to the degree of fixity of certain inputs. In the short run, where some inputs are fixed, the estimate of the increase in the net value of output can ignore the cost of the fixed inputs. But, in the long run, where all input costs must be covered, they cannot be ignored. Therefore, we would expect that for the same site and production processes, values estimated for a given supply for short-run contexts will be larger than values for the long run.

Another important distinction is between *periodic* and *capitalized values*. An annual or a periodic value estimate, is, for convenience, the customary form of the value of water used in everyday discussion and planning. However, in some contexts (such as with prices of perennial or permanent water rights), observed prices represent the capitalized present value of a stream of periodic values (called *asset* or capitalized values). Asset values are, of course, much larger than the corresponding periodic price.

Finally, the perspective from which benefits and costs are accounted for in a specific economic evaluation is called the accounting stance, which can be either *private* or *public*. The private and public accounting perspectives differ as to *how* input and product prices are measured (market prices or social prices). A value estimate from a private perspective uses the prices faced by the producers in their decision-making. The public accounting stance adjusts prices of inputs and outputs to reflect society's perspective. For example, adjustments to a public viewpoint may remove government subsidies for certain crops, such as cotton or rice, thus lowering the net income (economic value) attributed to water.

What types of methods may be applied to reflect these distinctions? Inductive approaches to valuing irrigation water policies, in that they study actual farmer behavior, universally reflect a private accounting stance. Some inductive approaches, such as observations on water rental markets, will represent both the short run and the periodic cases, but most, including hedonic property values and water rights markets, will represent both a long run and a capital asset value. Those inductive methods that measure net returns provide an at-source value (with delivery costs deducted), but production and cost function techniques provide at-site estimates. In contrast, the flexibility of deductive methods allow them to be used to estimate economic values either at-site or at-source, short-run or long-run, periodic or capitalized, and private or social accounting stances.

Hypotheses on Why Inductive and Deductive Results Might Differ

To analyze the potential sources of bias in deductive models, we can break down equation (1) into its component parts: revenues (price times yield) and the sum of non-water input costs. (It must be acknowledged that, for problems of water resource allocation over a several-decade planning horizon—such as for investments in water supply, or managing depleting aquifers–accurate forecasts of technology, costs and revenues is a most challenging task.)

Potential biases from empirical predictions. Overestimates of net returns are possible if, for a given planning situation, crop outputs or prices are overestimated. One common error in irrigation project planning has been to, in accordance with experience, forecast crop yields to rise with technological advance, but not to recognize the corresponding opposite world historical experience: falling inflation-adjusted crop prices. However, non-water input prices seem to be more stable and less susceptible to erroneous predictions. Another frequent mistake is to predict too large a proportion of high-valued specialty crops, and, as mentioned below, to attribute too large a return to water on such crops.

Potential biases from model mis-specification. In my experience, the main source of specification bias in deductive irrigation valuation is omitting some cost elements from a residual calculation. If some costs are ignored, a corresponding overestimate of residual returns will result. Several official manuals for water policy assessment from the US Bureau of Reclamation, OECD (Bergmann and Boussard 1976), and the World Bank (Gittinger 1982) have in fact advocated omitting farmers' costs of labor and/or capital, on the dubious, and sometimes implicit, grounds that these inputs do not reflect social opportunity costs. These assumptions led, in my view, to major overestimations of net social returns to irrigation. Also, where owned inputs (e.g., equity capital, managerial or other skilled labor) are specialized and themselves earn scarcity rents (as is the case for high-valued specialty crops), for which the actual opportunity costs may be not accounted.

Concluding Remarks

I have argued that under prevailing practices, and contrary to initial expectations, deductive estimates of irrigation water values yield larger estimates than do inductive methods. Two conclusions are offered. Given that nonmarket valuation involves not just finding the "one" accounting price, but is the process of assessing the welfare changes from alternative policy initiatives, and noting that there are many possible concepts of irrigation water value, different estimates are often to be expected even with location and production conditions held constant. Second, where long run public decisions are at stake, biases due to empirical prediction errors and improper model specification have been and still are present in the conventional deductive models which bring about overstatements of net social benefits to irrigation.

Doctoral students and others looking for research topics might consider one of several routes to confirm or reject my thesis about the actual differences between inductive and deductive measures of the economic value of irrigation water and the reasons for it. One fruitful step would be a formal meta-analysis of the irrigation valuation literature. Second, specific case studies could be performed where inductive and deductive analyses are performed for the same conditions and policy issues. Finally, the literature on *ex post* analyses of previous public investment decisions (see Wilson 1997; Fan and Hazell 2002) should be extended.

Author Bio and Contact Information

Robert A. Young has been on the faculty at Colorado State University since 1970 where he is now an Emeritus Professor of Agricultural and Resource Economics. His research emphasizes methodology of nonmarket economic valuation of water and interdisciplinary evaluation of proposed water policies and projects. Young was the recipient of UCOWR's Warren A. Hall Medal for 2004. His book *Determining the Economic Value of Water: Concepts and Methods* was published in January 2005. He can be contacted at Robert.Young@colostate.edu.

References

Bergmann, H. and J. M. Boussard. 1976. *Guide to economic evaluation of irrigation projects*. Rev. ed. Paris: OECD Publications.

Cicchetti, C., V. K. Smith and J. Carson. 1975. Economic analysis of water resource investments and regional economic growth. *Water Resources Research* 11(1): 1-6.

Fan, S. and P. Hazell. 2001. Returns to public investments in the less-favored areas of India and China. *American Journal of Agricultural Economics* 83(5): 1217-1222.

Gittinger, J. Price III. 1982. *Economic analysis of agricultural projects*. 2nd. ed. Baltimore, MD: Johns Hopkins University Press.

Torell, A., J. Libbin, and M. Miller. 1990. The market value of water in the Ogallala Aquifer. *Land Economics* 66(2): 163–175.

Wilson, Paul N., 1997. Economic discovery in federally supported irrigation districts: A tribute to W.E. Martin and friends. *Journal of Agricultural and Resource Economics* 22(1): 61-77.

Young, Robert A. 2005. *Determining the economic value of water: Concepts and methods*. Washington, D.C.: Resources for the Future.