Income Distribution Issues and Natural Resource Policy: Welfare Effects of Nonfederal Water Plans

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The need for regional economic models for benefit–cost evaluation of non-federally financed water plans is discussed. Input–output, econometric, and widely used programming methods all have shortcomings. A conceptual framework is proposed to measure Regional Economic Development (RED) benefits from water projects using a two stage procedure which combines mathematical programming production models and regional income accounting measures.

The proposed two stage framework separately accounts for (1) resource hiring decisions made by regional firms which are motivated by profits, and (2) RED benefits measurement, which is generally viewed as important to those who appraise regional resource projects. The first stage model takes as data the aggregate regional sector production function(s), availability of owned fixed resources (e.g. water, capital stock), supply schedules for purchased factors, and the export demand schedule. The solution to the first stage model generates equilibrium export demand prices/quantities and regional input usage patterns. Based on the resource usage patterns generated from the first stage, RED benefits from water supply increments are computed in the second stage.

The Bockstael and Strand paper demonstrates that even by accepting the compensation principle, one cannot avoid the ambiguities implied by aggregate welfare evaluation. Just and Zilberman look at the intrasectoral equity effects of certain common resource policies related to agriculture. My comments will focus on one intersectoral/aggregation related issue, namely the measurement of **regional** as distinct from **national** benefits of resource development projects, such as water. The Reagan administration continues to embrace a philosophy of increased state and local resource management and financial responsibility. Consequently, we need improved measures of regional economic development (RED) benefits of water and related resource development projects. This paper develops a framework for measuring such impacts.

Methods for valuing regional impacts of resource development projects are not new. However, I believe that the proposed method is fundamentally different from and represents an improvement over methods which are widely used to measure RED benefits of water resource development projects, such as input–output, econometrics, and existing programming approaches.

Accounting for Regional Efficiency Benefits

Since Eckstein [1958] and McKean [1958] articulated methods for measuring

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national economic efficiency benefits from water projects, economists have been reluctant to include regional "secondary benefits" (e.g. gross crop receipts from an irrigation project) as efficiency gains except when unemployment would otherwise exist. Little conceptual work has been developed which serves as a framework for measuring net RED efficiency gains. In appraising a resource development project from the regional stance, the economic question which presents itself is "will the value of gross **regional** product increase sufficiently to pay the project's costs and still leave the state (region) better off?" [Young and Gray, 1972, 1985].

Input–Output Analysis

Probably the current "state of the art" for assessing the regional economic effects of a water development project is input–output (I/O) analysis [Fisher]. However, Young and Gray [1985] and others have demonstrated that I/O can lead to overestimation of RED benefits of water development projects. In employing I/O, the measured value added by water to a sector's regional income typically rests on computing the "average value product" of water, computed as total sector payments to primary resources divided by total sector water used. Use of this procedure implicitly assigns a zero shadow price to all primary resources other than water, and thus ignores the fact that resources other than water are scarce. Assigning zero opportunity cost to other primary resources is questionable and is almost certain to result in value estimates which greatly overstate the true contribution of water to RED benefits [Young and Gray, 1985].

Econometric Approaches

In recognizing the limitation of I/O analysis in estimating RED benefits for water projects, Fisher [1978] proposed use of an econometric approach to measure marginal benefits from water supply augmentation projects. The procedure involves estimating a value-added equation for each relevant regional producing sector. In each equation both water and other value-added determinants such as sector wage rates, land values, and a price index of the sector's export products would be included. Based on the value-added parameter estimates, one could simulate the extra value added to the region (RED benefits) from water supply increments.

Given the inherent limitations of highly aggregated econometric analysis, Fisher's proposed method may be useful in estimating RED benefit water values where two special conditions are met in the region: (1) the effect of water as a determinant of value added is not swamped by other variables, and (2) water supplies actually change enough over the estimation period to permit statistically efficient estimates of water's regional income contribution [Fiore and Ward].

A Two-Stage Benefits Measurement Framework

As a framework for measuring RED benefits from resource development projects, I would like to propose a two-stage method which draws on the mathematical programming and economic theory literature of Samuelson [1952], Takayama and Judge [1964a, b], Duloy and Norton [1975], Penson and Fulton [1980], McCarl and Spreen [1980], and Bell, Hazell, and Slade [1982]. These authors and many others have shown that mathematical programming techniques can be used to simulate competitive producer resource hiring behavior in an environment of regional resource constraints such as water, land, and fixed capital. These programming methods can simulate multisector regional resource allocation through treating competitive equilibrium as mathematically equivalent to the maximization of consumer and producer surplus [Samuelson]. Examples include quadratic programming, or the more general "price endogenous mathematical programming" (PEMP). One attractive feature of traditional PEMP models is that by specifying the net surplus objective function, competitive equilibrium decision making by firms and consumers can be simulated over each sector. However, a major shortcoming of PEMP appears to have been ignored by many practitioners. Specifically, the shadow value associated with the water constraint derived from the solution does not in general measure marginal RED benefits from new water. It measures the net surplus (i.e., price) from extra water. Only under special circumstances discussed below will the two be equal.

An Illustration

Suppose that production of a region's export good (Z) is determined by an aggregate production function $Z = Z(X_1 \ldots X_n; K_1 \ldots K_m; W_o)$ of several regional inputs, $X_1 \ldots X_n$, which are assumed purchasable in competitive markets, and fixed inputs, $K_1 \ldots K_m$. The input, W (water) is "owned," unpriced, and fixed in supply, equal to W_o.

To begin the first stage, we follow McCarl and Spreen by supposing that in choosing the production level of (Z), regional producers act as if they solve the mathematical program

$$\text{Max } Z'G - .5Z'HZ - XE' - .5X'FX \quad (1)$$

where primes indicate matrix transposes. The export product demand function is:

$$P = G - HZ \quad (1a)$$

in which the export price, P, is a linear function of regional product output, Z. Although we use the example of a single export product, Z will in general be an n-dimensional vector of sector outputs. For the single sector case, G and H are demand intercept and slope parameters, respectively. The factor supply price of the i^{th} purchased regional input is:

$$r_i = E_i + F_iX_i \quad (1b)$$

From (1), (1a), and (1b) competitive regional producers act as if they maximize consumer surplus (area bounded by the product demand function and the demand price) plus producer surplus (total regional export sales revenues less input opportunity costs). Details are in McCarl and Spreen.

The constrained optimization model above takes as data the regional production function, availability of water, supply schedules for purchased variable factors (e.g., labor), availability of other fixed factors (e.g., land, buildings), and a demand schedule for the regional export product. The solution of the model through quadratic (or similar) programming methods generates an equilibrium product price, regional production, usage patterns for both purchased and owned factors, and imputed values of fixed factors, including water.

Regional Income Value of Water

The imputed value of water is our focus. The solution to (1) results in an imputed value of water, P_w, **given the producer's objective function** in (1). P_w **does not** measure the shadow value of incremental water based on the **regional income** objective, i.e., RED benefits.

Define the RED benefits of water as MB_w. Because MB_w is **not** the shadow value resulting from the optimum solution of (1), it must be computed **after** (1) has been solved. This is why we propose introducing the second stage.

For the second stage, one must first choose a suitable definition for regional income. Many are possible. Total rents to fixed inputs, e.g., land, is a popular welfare measure [LeVeen, Martin *et al.*]. The definition used in the regional income accounts is regional "value-added" [Young and Gray, 1985], i.e.

$$Y_r = P'Z - P_{xm}X_m \quad (2)$$

where value-added, Y_r, is total receipts from the sale of the aggregate regional product ($P'Z$) less expenditures on imports ($P_{xm}X_m$).[1]

Once a definition has been chosen for regional income as in (2), Y_r is computed under initial and terminal water supply conditions, based on the **result** of the optimal solution to (1). Specifically, one would compute

$$Y_{ro} = P^{*\prime}Z^* - P^*_{xm}X^*_m \quad (2a)$$

where starred values indicate values of the varibles in (2) taken from the solution to the first stage; Y_{ro} is the level of regional income which producers generate as a result of maximizing **their** objective function, constrained by the without-project amount of water, W_o.

The RED benefits of **extra** water are found by re-solving the two-stage problem, using the "with" project level of water, W_1.

Conclusions

It has been shown that use of a two-stage procedure, in which consumer plus producer surplus is the first-stage maximand, can simulate competitive equilibrium and computes regional benefits of new water. Consumer surplus is the area under the export demand above market price. Producer surplus (factor rent) is total factor payments less their opportunity cost. Opportunity cost is measured as the area beneath the factor supply schedule to the left of the factor employment level.

When will water's shadow price computed in the first stage of the programming model, P_w equal its marginal contribution to regional income, MB_w? Answer: when the change in consumer plus producer surplus from the extra water exactly equals the change in regional income. For the change in net surplus to equal change in regional income, two conditions suffice: (1) no gain in consumer surplus; i.e., export demand price must be invariant with respect to the gain in exports from the new water, and (2) all income gains to regional factors due to new water must take the form of pure rent.

Suppose that condition (1) holds true. Even so, condition (2) normally will not: for any factor (e.g., labor) whose employment is increased due to the extra water, part of its income gain will not be rent, even if that factor is already "fully employed" without the new water. Consequently, assuming a constant export price if some factors receive income gains other than pure rent, the regional income gain from the water, MB_w will **exceed** the imputed price of water resulting from the solution to the programming model, P_w.

There are several advantages of the proposed two-stage programming–income computation model. First, by employing an explicit producer-oriented objective function (producer-plus-consumer surplus) one can simulate resource hiring decisions of a competitive industry [McCarl and Spreen]. Water-using entrepeneurs are generally interested in their own income and not RED benefits. Second, the definition of regional income is flexible. Third, a regional production model can be defined in principle from any accounting stance desired, including state, local, individual, or any other. Fourth, increased water supplies could enter the region's export demand function as a **demand** shifter (i.e., a shifter in the G term in equation 1a) as a complement

[1] Nonmarket benefits are an important additional component of RED benefits from water projects. Such benefits could be added to the market based regional income flows defined by (2). Then, the RED objective would be interpreted as "real" regional income. It is well-known that resource development projects such as expenditures on improved water quality may have little effect on the regional income accounts defined in the market place, e.g., equation (2), and are produced primarily for their nonmarket benefit opportunities afforded.

to the traditional view of water as a **factor** of production. For example, in the arid west, water supply augmentations are progressively assuming a greater role in increasing the demand for lodging, restaurant and related export services associated with increased water-based recreation.

References

Bell, C., P. Hazell, and R. Slade. *Project Evaluation in Regional Perspective*. John Hopkins University Press, Baltimore, Maryland, 1982.

Bockstael, N. A. and I. E. Strand. "Distributional Issues and Nonmarket Benefit Measurement." *Western Journal of Agricultural Economics* 10(1985): 2 162–69.

Duloy, J. H. and R. D. Norton. "Prices and Incomes in Linear Programming Models." *American Journal of Agricultural Economics* 57(1975): 591–600.

Eckstein, O. *Water Resource Development: The Economics of Project Evaluation*. Harvard University Press, Cambridge, 1958.

Fiore, J. and F. A. Ward. "Water as a Factor in an Arid Region's Economic Growth: The Case of New Mexico's Rio Grande Basin." New Mexico State University Agricultural Experiment Station Research Report 563, May 1985.

Fisher, A. C. "Some Theoretical and Measurement Issues in Economic Assessment of Interbasin Water Transfers." In *Water Supply and Management*, Pergamon Press, Ltd, London 2(1978): 137–45.

Just, R. E. and D. Zilberman. "Income Distribution Implications of Natural Resource Policy Decisions." *Western Journal of Agricultural Economics* 10(1985):2 170–82.

LeVeen, E. P. A Political Economic Analysis of the 1982 Reclamation Act." *Western Journal of Agricultural Economics* 8(1983): 255–66.

McCarl, B. A. and T. H. Spreen. "Price Endogenous Mathematical Programming as a Tool for Sector Analysis." *American Journal of Agricultural Economics* 62(1980): 87–102.

McKean, R. N. *Efficiency in Government Through Systems Analysis*. John Wiley and Sons, Inc., New York, 1958.

Martin, W. E., H. Ingram, and N. K. Laney. "A Willingness to Play: Analysis of Water Resources Development." *Western Journal of Agricultural Economics* 7(1982): 133–39.

Penson, J., Jr. and M. E. Fulton. "Impact of Localized Cutbacks in Agricultural Production on a State Economy." *Western Journal of Agricultural Economics* 5(1980): 107–22.

Samuelson, P. A. "Spatial Price Equilibrium and Linear Programming." *American Economic Review* 42(1952): 283–303.

Takayama, T. and G. G. Judge. "Equilibrium Among Spatially Separated Markets: A Reformulation." *Econometrica* 32(1964a): 510–24.

Takayama, T. and G. G. Judge. "An International Activity Analysis Model of the Agricultural Sector." *Journal of Farm Economics* 49(1964b): 349–65.

Young, R. A. and S. L. Gray. "Economic Value of Water: Concepts and Empirical Estimates." Technical Report to U.S. National Water Commission, National Technical Information Service, PB210356, Springfield, Virginia, 1972.

Young, R. A. and S. L. Gray. "Regional Models, Welfare Economics and the Evaluation of State Water Plans." *Water Resources Research* forthcoming, 1985.