Measuring Foregone Direct Benefits of Irrigation Water Transfers: The Effect of Model Specification

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Introduction

In the arid parts of western North America irrigated agriculture continues to be by far the largest and often the lowest-valued water use. Growing urban water demands and a rise in the values placed on environment and instream flows have intensified the competition for limited water supplies. Market transfers of irrigation water to higher valued uses can be expected to play an increasingly important role for meeting these changing demands and improving the economic efficiency of water resource allocation.

Economic evaluation of proposed water rights transfers involves estimating if the direct economic benefits (DB) and secondary economic benefits (SB) in the receiving (purchasing) sector, net of physical transport and transactions costs are greater than the foregone direct economic benefits (FDB) and foregone secondary benefits (FSB) in the sector where the water is presently used.

An important but still controversial question of policy significance is conceptualizing and measuring the magnitude of FDB resulting from water rights transfers from irrigated agriculture. In addition to its role in studying water allocation policy, this information may be significant for assuring adequate compensation for sellers of water rights. Information on FDB is typically lacking because prices in properly functioning water markets, which in principle would adequately reflect the underlying foregone direct benefits, are often not observed and need to be estimated via modeling procedures.

Objective of Study

Our purpose is to show how different model specifications lead to different measures of FDB and perhaps to differing policy conclusions. (We ignore the separate but important question of FSB.) Two aspects of this task are of interest here:

- How to properly *identify and price non-contractual inputs* (those assumed to be owned by the firm), such as (a) management and entrepreneurial skills, and (b) land and other (non-water) natural resources.

- How to *specify the measure of water input*. The most often-used measure is (a) *delivery* (defined as the difference between water withdrawn and the amount of water lost in transit from the point of withdrawal to the point of delivery). (b) But *consumptive use* (or net water depletion, defined as delivery minus return flows—the amount of water returned via surface runoff and/or deep percolation) is perhaps of more significance. It is the water that is evaporated, transpired, incorporated into plant products, or otherwise removed from the immediate water environment. Some western States require that water rights transfers be limited to the estimated consumptive use, so the downstream uses dependent on return flows are not damaged.

Research Approach

The theoretical basis for determining by how much producers would be worse off from a reduction in water supply is the neoclassical theory of production and the theory of the firm (Young 2005).

The basic measure for the value of an un-priced limited input such as water is the *residual economic rent* attributable to that input. The general conceptual framework assumes: If the physical production function and the optimal quantities of all the other inputs are known and input and product prices reflect competitive market conditions, then these inputs' distributive shares can be deducted from the total value of product and the remaining economic rent can be imputed to the unpriced input (the residual claimant).

In the agricultural sector the so-called *residual imputation* method via enterprise budgeting has been the most frequently used approach to approximating the residual rent, especially in *ex ante* contexts. More advanced versions of the calculations can be performed by mathematical programming or even computable general equilibrium.

Although conceptually straightforward, in practice several problematic issues arise which so far have not been much examined in the literature. Even accurately specifying the physical production function, specifying technologies, and assigning correct prices for outputs and, in particular, non-water owned inputs are challenging. If, for example, in a long-run context of analyzing FDB owned inputs are neglected in calculating the residual claimant for water, then the value assigned to water is erroneously large because it includes returns not just to water, but to the ignored owned inputs. Results from such analyses would yield exaggerated estimates of FDB from decreased water supplies.

Previous Research

Early approaches to estimating FDB (e.g. Wollman, 1963; Hartman and Seastone 1970) relied on value-added measures (payments to primary resources) from regional Leontief input-output-type models. These were criticized (e.g. by Young, 2005) as overstatements of FDB for assuming zero opportunity costs for non-water value added elements. Representative residual or linear programming-based farm-model estimates include Hamilton, Whittlesey and Halverson (1989), Chang and Griffin (1992) and Taylor and Young (1995).

Some of the estimates in the literature have only inadequately accounted for non-water owned inputs. And, to our knowledge, none of the FDB estimates has so far been specified in terms of consumptive use as the measure of water input. In part, this is because consumptive use is, in practice, difficult to observe and some modeling approach is necessary.

Method of Study

Employing a linear-programming-based agronomic/economic model of crop production for a northern Colorado irrigation district (for details, see Scheierling, Young and Cardon 2006), we develop measures of foregone direct benefits (FDB) under four model specifications:

- FDB is shown first with a specification that calculates residual rents as returns to owned inputs (revenues minus contractual costs). These results are compared with what we regard to be a more theoretically correct specification that also deducts estimated opportunity costs of non-water owned inputs (here measured by values of non-irrigated land and a charge for management).

- We then calculate each of these estimates on a per-unit water basis: FDB per unit water delivered, and FDB per unit water consumed.

Table 1: Estimates of Net Income for Corn Silage (1 Acre)
Four irrigations (each with a net infiltration of 3 inches) with flexible pipe

Description	Without Owned Inputs Value/Cost per Acre	With Owned Inputs Value/Cost per Acre
A. Total Revenue	**530.67**	**530.67**
B. Variable Costs		
a. Seed	36.00	36.00
b. Fertilizer		
1. Anhydrous Nitrogen	9.12	9.12
2. 10-34-0 w/zn	7.50	7.50
c. Chemicals		
1. Lasso II 15 G (Herbicide)	5.45	5.45
2. Banvel (Herbicide)	4.66	4.66
3. Counter (Insecticide)	15.75	15.75
d. Irrigation Operation & Maintenance	14.25	14.25
e. Machinery/Equipment (Custom)		
1. Disc	6.00	6.00
2. Plow	15.00	15.00
3. Apply Anhydrous Nitrogen	6.00	6.00
4. Apply Herbicide	4.00	4.00
5. Plant	10.00	10.00
6. Row Crop Cult	6.00	6.00
7. Row Crop Cult	6.00	6.00
8. Ditch	8.00	8.00
9. Combine	98.00	98.00
10. Truck	12.25	12.25
f. *Management (5% of total revenue)*	*0.00*	*26.53*
g. Interest on Variable Costs (9% for 4 months)	7.92	8.72
Total Variable Costs	**271.89**	**299.22**
C. Annual Overhead and Annualized Capital Costs		
a. Real Estate Taxes	10.00	10.00
b. Irrigation Equipment	11.99	11.99
c. *Land Charge (Non-Irr. Winter Wheat)*	*0.00*	*22.79*
d. Overhead Costs (5% of total variable costs)	13.59	14.96
Total Overhead and Capital Costs	**35.58**	**59.74**
D. Net Return	**223.20**	**171.71**
E. Annual Cost of Water Supply		
a. Variable Cost of Water Supply	20.18	20.18
b. Fixed Cost of Water Supply	31.5	31.5
Total Cost of Water Supply	51.68	51.68
F. Net Income	171.52	120.03
Water Delivery	2.50 acre feet	2.50 acre feet
Net Income per Acre Foot of Water Delivery	68.61	48.01
Consumptive Use	1.51 acre feet	1.51 acre feet
Net Income per Acre Foot of Consumptive Use	113.59	79.49

Table 2: Estimates of Net Income for Irrigation District (40,000 Acres)

Description	Without Owned Inputs Value/Cost for District	With Owned Inputs Value/Cost for District
Net Return	**8,367,467**	**6,373,573**
Annual Cost of Water Supply	2,067,067	2,067,067
Net Income	**6,300,400**	**4,306,506**
Water Delivery	120,324 acre feet	120,324 acre feet
Net Income per Acre Foot of Water Delivery	**52.36**	**35.79**
Consumptive Use	63,504 acre feet	63,504 acre feet
Net Income per Acre Foot of Consumptive Use	**99.21**	**67.81**

Table 1 presents a sample unit budget that illustrates how our analysis is built up for a representative crop (corn silage in this example). Data refer to 1993. The columns show the calculations for net returns for both specifications regarding owned inputs: where their opportunity costs are ignored, and where estimated charges for owned inputs are deducted. The charge for management is assumed to be 5% of total revenues. For the opportunity cost of land, we use an estimate of the net returns to non-irrigated winter wheat on similar soils. Water *delivered*, using flexible pipe technology and four irrigation events, is estimated to be 2.5 acre feet per acre, while water *consumed* is estimated to be about 1.51 acre feet per acre.

The bottom of Table 1 shows estimated FDB in net income per acre foot of water delivered and water consumed for each owned-input specification:

- FDB estimates per unit delivered are considerably (about 40%) larger where owned input charges are assumed to be zero.

- For each owned input price specification, the FDB estimate is significantly (about 65%) higher for the *consumptive use* specification than for the *delivery* version.

Model Results for the Irrigation District

Table 2 gives our results from the model, which represents cropping patterns with the five main crops (alfalfa hay, corn grain, corn silage, edible dry beans, and sugar beets) in the irrigation district. These crops are assumed to be irrigated according to the distribution of existing practices, allowing us to specify delivery and consumption per acre for each crop.

For the irrigation district as a whole, when owned inputs are neglected, FDB estimates per unit delivered are 46% higher than when they are included. And, of course, FDB for the consumptive use specification are larger than that for delivery—in inverse proportion to their estimated quantity per acre.

Conclusions

It is seen that a wide range of FDB estimates per acre foot is derived depending on the chosen model specification. As indicated above, for the input costs specifications, we prefer the specification in which an estimated opportunity cost is charged for owned inputs: management and non-irrigated lands.

For the water quantity measures, the consumptive use measure indicates that the "high" prices observed on Colorado water markets may in part reflect actual FDB in consumptive use terms as much as reflecting the conventional assumption of unearned rents from strong urban and environmental demands.

Literature Cited

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