Economic Value of Water in Tennessee Estimated by Combining Input-Output Coefficients with Linear Programming

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Background

Water stress in the southeastern US is expected to increase due to population growth, climate change and increased irrigation by agricultural producers. For example, the number of irrigated acres in Tennessee increased by over 200% from 1997-2012 (USDA, 2013). Concerns over water availability and allocation are also increasing. Gaining a better understanding of current and future water withdrawals (also called "use") and their economic value is an important first step for responding to these concerns. Determining these values for water provides a basis for designing and evaluating policy to efficiently allocate water amongst competing uses.

Objective

This poster presents an extension of Blackhurst et al.'s (2010) methodology to estimate water use coefficients and Henry and Bowen's (1981) methodology to estimate the shadow value of water for economic sectors using input output linear programming (IOLP).

Methods

The economic value of water is measured as water use per dollar of output for each industry. The algebraic input output model is:

$$W = D(I - A)^{-1} \cdot Y$$

where *W* is a vector of total water use for each industry, *D* is a matrix with diagonal elements representing total water use per dollar of output, *I* is an identity matrix, *A* is a direct requirements matrix from an Input-Output model of the regional economy, and *Y* is a final demand vector.

Determining Water Use Coefficients

The Impact Analysis for Planning model (IMPLAN) provides the information needed for understanding inter-industry transactions through the direct requirements matrix, *A*. To derive matrix *D*, water coefficients are determined using the publicly available data and output of final demand from IMPLAN. To determine the water coefficients, estimated water use for each sector is calculated and then divided by the total output of a sector. The amount of water used per unit of production is:

$$W_i^{Coeff} = \frac{W_i^{Use}}{X_i},$$

where W_i^{Coeff} is the water coefficient for sector *i*, W_i^{Use} is the estimated total water use of sector *i*, and X_i is the total output of sector *i*.

Methods (continued)

The IOLP model is written as:

Maximize GRP = CX

Subject to:

1. $Y_F \geq (I - A)X \geq Y$
2. $\sum_{i=1}^{536} W_i^{Coeff} X_i \leq W_T$
3. $\sum_{i=1}^{536} L_i X_i \leq L_T$

where *GRP* is gross regional product, *C* is value added coefficients from IMPLAN, Y_F is projected final demand, W_T is the total water availability, L_i is the labor requirement for sector *i* per unit of production, and L_T is the total labor availability.

Progress

Currently water use coefficients are being determined on the county level for the state of Tennessee. The USGS (2010) provides water withdrawals per county for the eight aggregate sectors shown below.

Table 1. TN Estimated Water Use by USGS Sector

USGS Sector	Water Use (000s of acre feet per year)	% of Total Water Use
Public Supply	502	5.82%
Domestic	43	0.50%
Irrigation	81	0.93%
Thermoelectric Power	6493	75.32%
Industrial	869	10.08%
Mining	16	0.19%
Livestock	31	0.36%
Aquaculture	59	0.68%

ǂ "Public supply deliveries to domestic" was not included in the Public Supply sector because there is not an economic sector in IMPLAN for household water use.

The water use of the eight USGS sectors is first disaggregated into North American Industry Classification System (NAICS) sectors. NAICS sectors are then grouped into the 536 IMPLAN sectors. Thus far, estimated water withdrawals by county have been completed for the irrigation, livestock, and aquaculture USGS sectors all the way down to the IMPLAN level. These estimates were determined using the Entropy method.

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Entropy Method

The Entropy Method is:

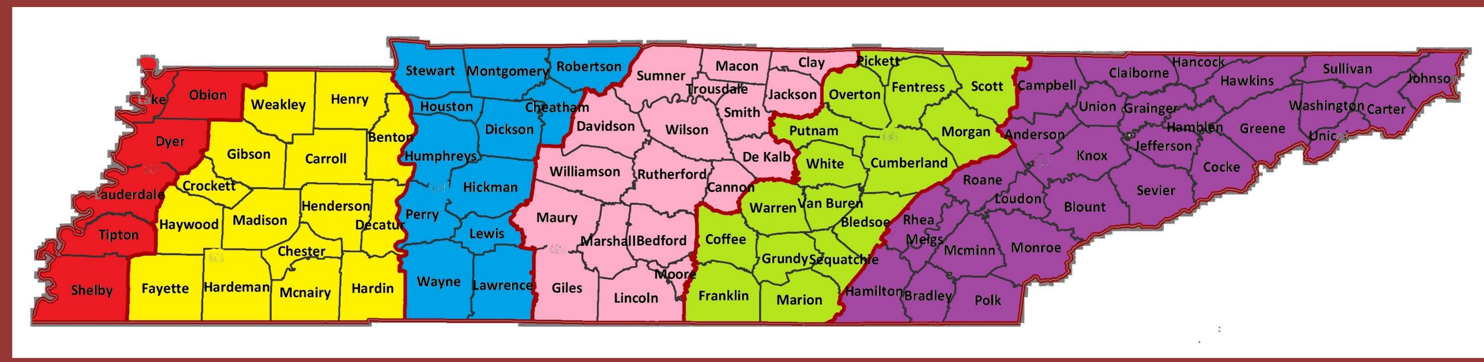
Minimize Z=0

Subject to:

$$W_k^{USGS} - \sum_{j=1}^{j} \exp(-1 - \lambda * B_j) * B_j = 0$$

where W_k^{USGS} is the USGS estimated water withdrawal for county *k* and B_j is a weight for each sector *j*. For example, in the irrigation calculation, water withdrawal for each crop sector was weighted by the number of irrigated acres per sector. Irrigated acreage was computed using data from the 2007 Census of Agriculture. Undisclosed values in the Census were estimated using regional averages based on Policy Analysis System (POLYSYS) regions. The regions are shown below.

POLYSYS Regions for Tennessee



Future Research

Remaining water use coefficients will be estimated and implemented into the input output linear programming model. A comparison of industry shadow prices will be used to draw conclusions about potential allocation plans under various water availability scenarios.

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