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REDUCING THE AGRICULTURAL SUBSIDY ON U.S. BUREAU OF RECLAMATION LANDS

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REDUCING THE AGRICULTURAL SUBSIDY ON U.S. BUREAU OF RECLAMATION LANDS

One negotiation of the General Agreement on Trade and Tariffs is the elimination of irrigation subsidies on U.S. Bureau of Reclamation (BOR) surface irrigation water. The United States Department of Agriculture (USDA) and other Federal agencies are interested in this policy or other policies, such as reduced BOR water allocations for agriculture, that might encourage irrigators to grow non program crops[1] and thus help reduce future government expenditures on agriculture subsidies. In 1987, these subsidies amounted to $26 billion.

In 1986, 10.1 million agricultural acres were served by Bureau water. Total BOR water delivered to farms was 27.2 million acre—feet, (U.S. Department of Interior). Of these 10.1 million acres, program crops accounted for one third or 3.4 million acres. Preliminary estimates by the USDA suggests that the combined water and program crop subsidy in Bureau regions was $575 million. Changes in water allocations or alternative pricing of BOR water would have a direct impact on this component of Federal agricultural subsidies.

A conventional approach for analyzing the impact of reduced BOR water allocation and/or higher prices for water[2] would be to estimate an acreage supply function using time series data and then examine the elasticity of supply with respect to water allocation. However, the estimated elasticity would be useful as policy guide, only if the relationship between water allocation and program crop acreage was stable. The conventional approach ignores price expectations that may change with different agricultural policies or other macroeconomic conditions. Chavas and Lucas argue that different government policies change the decision environment facing economic units and result in

ABSTRACT

We estimated the elasticity of program crop acreage to reduced water allocation in the U.S. Bureau of Reclamation surface irrigation projects. The elasticity estimates were then tested for stability using the Brown–Durbin Evans (BDE) test. Reduced water allocations and/or increased water prices would be an ineffective policy for reducing U.S. agricultural surpluses because BOR lands are a small percent of total crop acreage, but for a 20% reduction in agricultural water allocation, the subsidy saving from BOR lands would be in the range of $50 million per year or $9.60 per acre foot. The estimated savings can be predicted with significant reliability because the BDE test indicates that there has not been significant changes in the crop allocation function despite 20 years of a changing economic environment and government policies.

structural changes or shifts in the equations representing market behavior.

The estimated subsidy costs of BOR lands can only be predicted with reliability if there has not been significant changes in the crop allocation function despite 20 years of a changing economic environment and government policies. Policies such as the numerous farm bills, the 1982 BOR Reform Act, the 1973 and 1978 Russian grain agreement and embargo would all be likely candidates to have shifted the aggregate crop function. If these policy changes were significant, the estimated elasticities of program crops in BOR acreage would be an invalid basis for a comparative policy analysis. Thus, the reliability of the elasticity estimate is as important for policy making as its magnitude.

Our objectives are three fold: 1) Assess the potential of reduced BOR agricultural water allocations as a policy variable for reducing program crop acreage. Specifically, we present the estimated elasticity of water allocation on the aggregate supply of program crops in BOR projects; 2) Estimate the potential subsidy saving resulting from a 20% reduction in BOR water (5.4 million acre feet) allocated to agricultural use and 3) Analyze the estimated elasticity for stability, indicating the robustness with which the estimate can be used for new agricultural policies and price expectations that are different from the past.

A Model of Program Crop Supply on Surface Irrigated Acreage

In this section we develop a model to predict the aggregate amount of program crop acreage allocated by farmers within BOR irrigation projects. The model is an extension of a traditional supply equation derived directly from the behavioral assumptions of profit maximization of the farmers.

We assume that farmers decide on acreage allocations from inputs and outputs prices and the quantity of water available from the BOR project (most BOR districts within a project do not price water by unit usage, rather they allocate a fixed quantity or share of the reservoir for a flat fee). There are two concepts of water employed in this analysis; the stock of water (available water) in the BOR reservoir and the annual allocated water to the farmers. Because of rotations and risk management strategies, cropping decisions are a strategic plan involving several years (Dudley and Burt). Year to year fluctuations in allocated water may involve some changes in the short–run cropping pattern but long–term changes in the cropping pattern would require more permanent change in the policy guiding water allocations. We incorporate the idea of "Malthusian Flow scarcity" (Hall and Hall) as representative of long term changes in allocation of water. Water allocations (flow) are a function of the available stock in the reservoir. The ratio of water allocated to the stock in the reservoir reflects in part its current versus future scarcity. The higher the ratio, the higher the current scarcity relative to future needs. Following Hall and Hall, we advocate that this ratio approximates the "Malthusian Flow Scarcity" or the shadow price of water[3]. Any inter year change in the allocated water, holding the proportion constant, would not induce a permanent change in the cropping pattern. However, a different policy or physical reality, such as very low or high reservoir levels, that changes the proportion of allocated to available reservoir water implies a different scarcity price for water and would shift the cropping pattern.

The farmer's major decision is to select an optimum output mix treating water as a fixed factor[4] with input/output prices as exogenous. Because of the water constraint, there is a production frontier between program crops and other crops. The production frontier, in its implicit form, can be written as

$$(1) \quad F(Y_1, Y_2, W) = 0,$$

where Y_1, is acreage of program crops; Y_2 is acreage of all other crops and W is share of allocatable water from the district. The explicit form of equation (1) is

$$(2) \quad W = g(Y_1, Y_2)$$

Beattie and Taylor have shown that if output prices are relatively constant, the farmer's profit maximization problem is equivalent to revenue maximization, and thus his objective is as follows:

$$(3) \quad \text{Maximize} \quad V = \sum_i P_i Y_i , \quad i = 1,2 ,$$

$$\text{subject to} \quad \overline{W} = g(Y_1, Y_2)$$

$$\text{and} \quad \overline{Y} \equiv Y_1 + Y_2 ;$$

where the bar indicates exogenous value of the variables for $\overline{W}$ (water share) and $\overline{Y}$ (total land).

The equivalent Lagrangian function is

$$(4) \quad L(Y_1, Y_2, W, P_1, P_2, \lambda) = P_1Y_1 + P_2Y_2 + \lambda [\overline{W} - g(Y_1, Y_2)]$$

$$+ \mu [\overline{Y} - (Y_1 + Y_2)],$$

where P_1 and P_2 are the product prices, and λ and μ are the Lagrangian multipliers

The first order condition for constrained revenue maximization are

$$(5) \quad \frac{\partial L}{\partial Y_1} = P_1 - \lambda g_1 - \mu_1 ,$$

$$\frac{\partial L}{\partial Y_2} = P_2 - \lambda g_2 - \mu_2 ,$$

$$\frac{\partial L}{\partial \lambda} = \overline{W} - g(Y_1, Y_2),$$

and $$\frac{\delta L}{\delta \mu} = \overline{Y} - (Y_1 + Y_2) .$$

Simultaneous solution to these first order conditions results in the product supply equations (6) which are conditional (superscript c) on the level of the fixed factor:

$$(6) \quad Y_1^c = Y_1^c(P_1, P_2, W) ,$$

$$Y_2^c = Y_2^c(P_1, P_2, W) ,$$

$$\lambda^c = \lambda^c(P_1, P_2, W) ,$$

and $$\mu^c = \mu^c(p_1, p_2, W) ,$$

Although the proportion of allocated water to the reservoir stock is fixed from the farmer's perspective, the variation in the fixed factor permits us to conduct the comparative static analysis and analyze the impact of long term changes of water allocations on program crop acreage.

Because of crop rotations and long term price expectations, farmers may delay changes in crop acreages for short term price changes. Thus, we have specified previous acreage of program crops as a lagged explanatory variable of current acreage. The program crop supply equations in (6) translate into the following estimable supply equation,

$$(7)\ Y^t = f(Y^{t-1}, P_y^t, P^t, W^t),$$

where Y^t is program crop acreages; P_y^t is its own product price; P^t is a vector of prices of competing crops; W^t is the proportion of water allocation relative to the stock; Y^{t-1} is lagged program crop acreages and t represent time. The specific regression equation used in the analysis is

$$(8)\ \ln Y_t = \beta_0(t) + \beta_1(t)\ln Y_{t-1} + \beta_2(t)\ln P_y + \beta_3(t)\ln P_f + \beta_4(t)\ln P_v +$$

$$+ \beta_5(t)\ln P_m + \beta_6(t)\ln W + e_t,$$

where P_f, P_v and P_m are per acre prices of forage, vegetables and miscellaneous crops respectively, all of which compete with program crop acreage. The error term, e_t, is assumed to be distributed normally with zero mean and constant variance. The variables of equation (8) are in natural logarithms so that estimated coefficients are the elasticities and readily interpretable.

Test for Stability of the Coefficients of Program Crop Acreage

Testing the stability of a structural equation has recently been widely discussed by Hsiao. Tests for parameter constancy include Brown–Durbin–Evans test, (Khan, Garbade), Kalman filter, (Chavas), Lagrangian–multiplier test, (Breusch and Pagan), or Maximum–likelihood estimation (Harvey, and Harvey and Phillips). We applied the Brown–Durbin–Evans (BDE) test since it is simpler than others and adequately serves the purpose of identifying structural change.

We estimated supply equations for the aggregate BOR acreage within a recursive residual framework. This procedure determines the stability of the coefficients of the supply equation over the entire sample period. With stable coefficients, an out of sample prediction of the impact of reduced water allocation on the supply of program crops in BOR can be made with some confidence. Changes in coefficients (instability) would indicate that price expectations, agricultural programs, water policies and/or macro economic conditions have caused a significant shift in cropping patterns and the estimates of elasticities are suspect.

Our null hypothesis is that the coefficients of the supply equation are constant over time. The alternative hypothesis is that those coefficients are not stable:

$$(9)\ H_0:\ \beta_i(1) = \beta_i(2) = \ldots\ldots = \beta_i(T), \quad i = 0..\ 6, \text{ and } t = 1,\ldots T;$$

$$(10)\ H_A:\ \beta_i(1) \neq \beta_i(2) \neq \ldots\ldots \neq \beta_i(T); \quad i = 0\ldots 6, \text{ and } t = 1,\ldots T.$$

BDE tests the hypothesis that in a time series data, the coefficients of the regression model estimated from a subsample (say r–1 observations) that are used to predict the r–th observation will yield the same results when compared to coefficients of any other subsample (say r+m th observations) used to predict the T–th observation. The procedure is recursive starting with a (r–1) base subsample of coefficients. The subsample is used to predict the following year, then the subsample is expanded to include the next year's observations. The recursive equations for estimation are outlined in Brown, Durbin and Evans and also in Khan.

The stability of the coefficients is checked by a ratio test of transformed residuals. Specifically, the procedure utilizes a statistic, S_r, which equals the ratio of the sum of squares residuals of one period prediction from the k+1 period to the r–th period, to the sum of squares of one period prediction error from the k+1 to the T–th period. T is the sample size and k, the number of explanatory variables. Brown, Durbin and Evans showed that if the regression coefficients are stable (constant) over time then the expectation of the S_r statistic, $E(S_r)$ lies along its mean value line. If the time path of the estimated value of $\hat{S}_r$ deviates from its expected path by a specified significance level, changes to the coefficients have occurred. The statistic, S_r, is computed as

$$(11)\quad S_r = \left\{ \sum_{j=k+1}^{r} w_j^2 \right\} \div \left\{ \sum_{j=k+1}^{T} w_j^2 \right\} ;$$

where

$$(12)\quad w_r = \frac{Y_r - X_r' \beta_{r-1}}{\sqrt{1 + X_r' (X_{r-1}' X_{r-1})^{-1} X_r}} \quad ; \quad r = k+1, \ldots . T;$$

and w_r are transformed residuals. Tests of significance can be performed by drawing a pair of lines defined by $S_r \pm C_0 + (r-k)/(T-k)$ which are parallel to the mean value line. The hypothesis of constancy of the regression coefficients is rejected if the sample path of $\hat{S}_r$ crosses either of these significance line. The statistic C_0 is distributed as Pyke's modified Kolomogorov–Smirnov statistic. Values for various significance level are provided in Durbin.

Data

The Bureau of Reclamation publishes annual reports on crop production of 110 surface irrigation projects that it manages throughout the Western U.S. Because of missing data, we eliminated 13 projects from the data base, leaving 97 observations. Data include acreages of various crops, per acre prices of crops, water allocation and available water supply. Since program crops include grains, rice and cotton, the price per acre was a weighted average based on the percentage of acreage of specific program crops for a project. The available data covers the period 1965 – 1985 and is utilized in this analysis for the estimation. As outlined in the model section, we used the relative share of water allocation as proxy variable for water price for this study. Water allocation serves as a good approximation to water price since the water allocation relative to total supply of water in the reservoir is fixed for all the districts and hence any price effect (increase/decrease) will be equivalent to that of a reduction/increase of the water allocation for the project.

Results

For the aggregate program crop acreage of all 97 projects, the null hypothesis, constancy of regression coefficients, is accepted. The plot of the S_r statistic, shown in Figure 1, stays within the confidence bounds. Evidently, changes in government programs, price expectations and water policies during the last 21 years have not caused any shifts in the basic supply equation of aggregate program crops in BOR projects.

For the pooled time series cross sectional data, the aggregate supply function works fairly well, Table 1. Surprisingly, neither the constant term or previous year crop acreage are significant. Program crop prices and competing non program crops have the expected opposite signs and are significant at the 10 percent confidence level.

Water allocation (water price) is a significant though an inelastic factor in determining program crops allocation. The estimated value is positive and significantly different from zero at the 10% confidence level. The elasticity of program crop acreage to water allocation is 0.42. With this elasticity, a 20% reduction in water allocation for all 97 projects would result in 5.4 million acre feet released from agricultural use. The reduction in program crop acreage would be 8.5% or 284,000 acres. Given the 1987 subsidy of $170 per acre for BOR program crop acreage, this reduction would amount to a subsidy savings of $49 million.

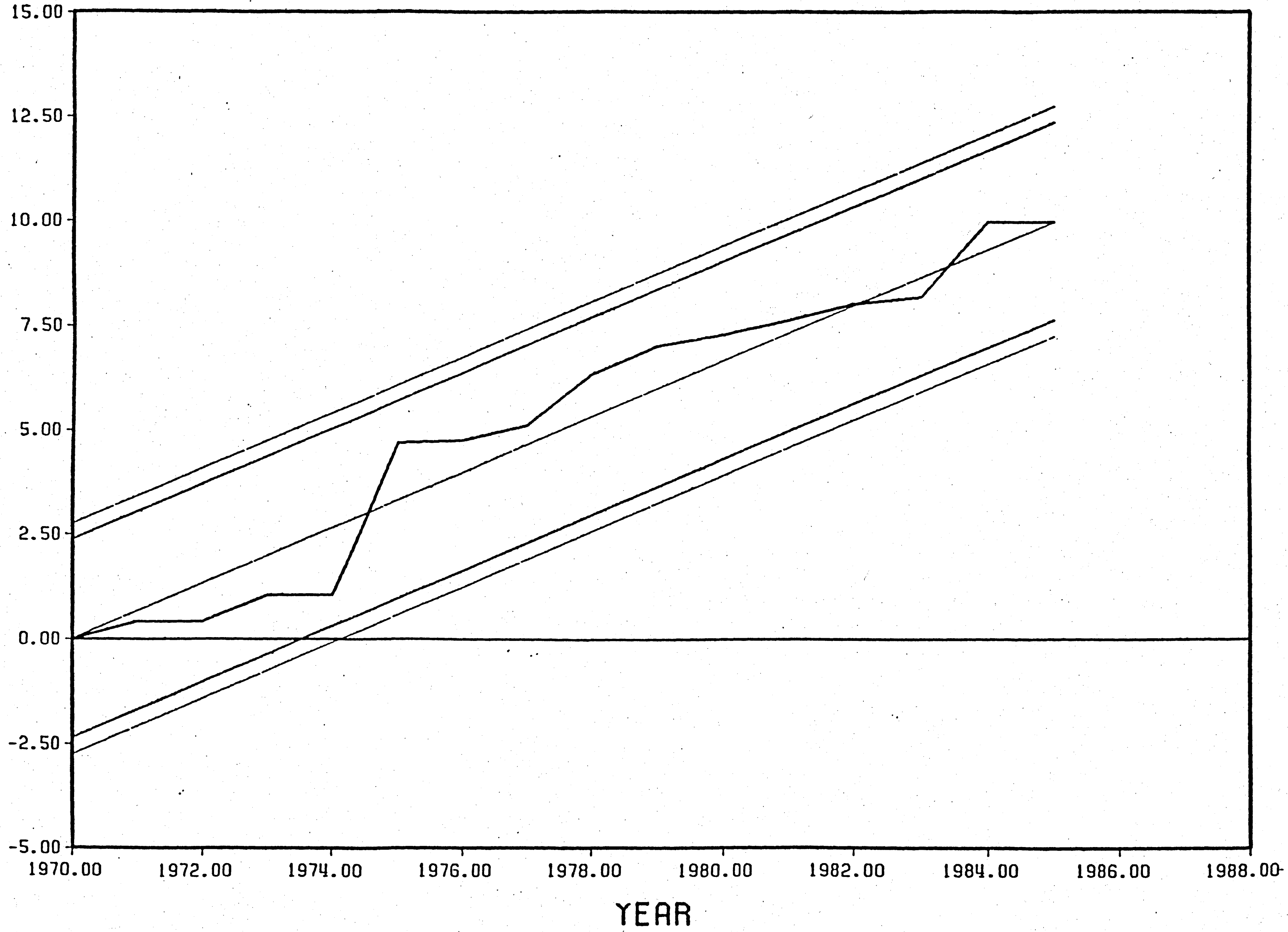

Figure 1. Test of structural change for Bureau of Reclamation aggregated acreage in program crops.

Table 1: Equation for Aggregate Program Crop Acreage in U.S. Bureau of Reclamation Irrigation Projects

Estimated Elasticities of Supply Equation – No Structural Change

const	Y_{t-1}	$P_y(t)$	$P_v(t)$	$P_p(t)$	$P_m(t)$	W(t)	R^2
4.005	–0.01	0.49	–1.21	0.28	0.42	0.43	0.51
(0.98)	(–0.47)	(2.14)	(–3.32)	(1.35)	(1.37)	(1.32)	

t – values are in parentheses

Conclusions

Reduced water allocations and/or increased water prices would be an ineffective policy for reducing U.S. agricultural surpluses because BOR lands are a small percent of total crop acreage. However, for a 20% reduction in agricultural water allocation, USDA direct subsidy savings from BOR lands would be in the range of $50 million per year. By itself, the reduction in subsidy would save $9.60 per acre foot, which is often more than current prorated cost of water from BOR districts. The estimate of the subsidy can be predicted with significant reliability as our stability tests indicate.

Substantial amounts of water would be freed for municipal and industrial use by the 20% reduction in water allocated to agriculture. The benefit to society would depend on the alternative uses of the approximately 5.4 million acre feet, either released into major river basins or retained in reservoirs for future uses. For perspective, 5.4 million acre feet per year would supply a metropolitan region with a population exceeding 10 million. As a policy for increasing non agricultural water availability, however, these results must be considered in the context of the aggregate supply. The water releases would be dispersed throughout the Western U.S. which, because of location may not have high valued alternative uses. Certainly, on the Colorado River and Rio Grande where there is competition for urban uses of water, released water would have high valued use. Ward has estimated a high recreational value for instream water uses. Whittlesey, Hamilton and Halverson have indicated a high value for water in hydroelectric generation in the Colombia River basin. The actual opportunity value of water in non agricultural uses would require analysis of regional and local impacts of individual projects.

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