Slippage in Forecasting Irrigation Water Demand:

An Application to the Georgia Flint River Basin

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Abstract

This study identifies the presence of slippage and the pitfalls associated with not considering economic substitution and expansion effects in measuring changes in water demand. Based on estimates from the Georgia Flint River Basin, the analysis indicates a 13% slippage caused by disregarding the role of economic determinants.

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As population pressures place increasing strain on our limited supply of natural resources, mechanisms designed for allocating this supply among competing demands are required. This limited supply is particularly acute in our demand for water. In a U.S.D.A., Natural Resources Conservation Service (USDA, NRCS) study, greater pressure on water resources in the tri-state area of Alabama, Florida and Georgia is the root cause of ensuing water negotiations and law suits among these states. According to this study, agriculture within Georgia is the major consumptive water user.

The current five-year drought in the Southeast has resulted in greater uncertainty in agricultural yields. This uncertainty has accentuated the demand for agricultural water use (irrigation) in the face of restricted supply. Attempting to aid in allocating water within the tri-state area the Georgia Legislature in February 2001 passed the Flint River Drought Protection Act (FRDPA). A component of this act was to hold an auction among southwest Georgia agricultural producers, with water permits, for the withdrawal of acreage from irrigation using perennial surface water sources in 2001. On March 17, 2001, bids to suspend irrigation were submitted. After five rounds of auction, Georgia's Environmental Protection Division (EPD) declared the auction closed with the EPD accepting offers on 209 of the 347 water permits registered at an average offer price of $135.70 per acre. This auction withdrew slightly more than 33,000 acres of farmland from irrigation. The EPD estimated removing 33,000 acres from direct surface water irrigation would result in approximately a 130 million-gallon daily increase in the Flint River water flow and its tributaries (Georgia Environmental Protection Division, 2001).

This estimate of water savings from reduced crop acreage is obtained using the Blaney-Criddle (BC) formula (USDA, SCSED). Blaney and Criddle found the amount of water consumptively used by crops during their normal growing season was closely correlated with mean monthly temperatures and daylight hours. They developed coefficients that can be used to convert consumptive use data for a given area to other areas for which only climatological data are available. The net amount of irrigation water necessary to satisfy consumptive use is found by subtracting the effective precipitation from the consumptive water requirement during the growing or irrigation season.

The actual reduction in water use from reduced irrigated acreage is driven by changes in the distribution of crops producers choose to irrigate. This change in crop distribution resulting from reduced irrigation acreage is determined by the expected profitability of competing crops. Considering the possible economic substitution and expansion effects associated with changes in agricultural prices, will accurately predict this change in crop distribution. Conventional physical models do not consider these substitution and expansion effects in determining agricultural water demand. The difference in a physical model calculation of change in water demand and the actual change is called slippage. In contrast, an econometric model based on a theoretical model addressing economic substitution and expansion effects will consider these effects, and thus will directly address this slippage problem. The research underlying this paper identifies the presence of slippage and pitfalls associated with not considering economic substitution and expansion effects in measuring changes in water demand. Analysis of the FRDPA indicates a 13% slippage occurs when disregarding the role of economic determinants.

Theoretical Model

The demand for irrigation water is a derived demand evolving from the value of agricultural products produced. Static and deterministic empirical models of water demand indicate adoption of modern irrigation technologies depends on price of water, labor, output level, output prices, soil slope, water holding capacity and climate (Caswell and Zilberman; Lichtenberg; Nieswiadomy; Negri and Brooks; Schaible *et al.*).

The deterministic models are effective in assessing seasonal water demand and irrigation technology choices by risk neutral producers. However, given risk in yields and prices, there is uncertainty involved with the profits of an enterprise. Irrigation is an example of a risk-reducing technology. The decision to irrigate by a risk averse producer is appropriately modeled through techniques allowing the effects of risk in decision making models. The major analytic tool for solving decision problems under risk is the expected utility, EU, model. It is assumed a producer maximizes expected utility by allocating the total amount of irrigated acreage available among competing crops.

Consider a producer in a given county engaged in producing n crops over A acres of irrigated land. Let A_i denote acres of the i^{th} irrigated crop with a corresponding yield of Y_i per acre. Yield Y_i is sold at the market price of p_i per unit of yield. The above activity results in the following revenue, R, function for the representative producer

$$R = \sum_{i=1}^{n} p_i Y_i A_i$$

Revenue is a linear function of stochastic prices and yields. By assumption, the vectors of prices $\vec{P} = p_1, \ldots, p_n$ and yields $\vec{Y} = Y_1, \ldots, Y_n$ are unobserved at the time of acreage allocation, the vector of acreages $\vec{A} = A_1, \ldots, A_n$ is to be determined by the producer given the risky revenue R.

Let the total variable cost of production, C, be

$$C = \vec{c}'\vec{A},$$

where $\vec{c} = c_1, \ldots, c_n$ with c_i as the variable cost of production per irrigated acre of the i^{th} crop. It is assumed that this total variable cost, C, for production is known with certainty given input prices and per-acre costs are known at the time of irrigated acreage commitment.

A constraint on the irrigated acreage requires all land be allocated to one of the n crops and that irrigated acreage does not exceed the total available acreage.

$$(1) \qquad \sum_{i=1}^{n} A_{iy} = A_y, \qquad y = 1, 2, \ldots, m.$$

Variable A_{iy} denotes the irrigated acres of the i^{th} crop in county y and A_y is the total irrigated acres available in the y^{th} county. A producer also faces a technology constraint represented as

$$(2) \qquad f(\vec{A}) = 0,$$

where $f(\vec{A}) = 0$ is the production frontier representing the multiproduct multifactor technology of the firm.

If the representative firm maximizes expected utility from total profit, π, under competition, then the decision model is

$$(3) \qquad \max_{\vec{A}} EU(\pi) = \max_{\vec{A}} EU(\vec{\pi}'\vec{A}),$$

subject to the acreage constraint (1) and technology constraint (2). The profit accruing from the i^{th} crop is

$$\pi_i = (p_i Y_i - c_i),$$

with $\vec{\pi} = \pi_1, \ldots, \pi_n$.

Equation (3) indicates that the acreage decision $\vec{A}$ is made under both price and production uncertainty. Both yields $\vec{Y}$ and output prices $\vec{P}$ are random variables with given subjective probability distributions. Consequently, the expectation operator in (3) over the stochastic variables $\vec{Y}$ and $\vec{P}$ is based on the information available to the firm at planting time. The optimization model in (3) has direct economic implications for the optimal irrigation acreage allocation, $\vec{A}^*$. If the firm is not risk neutral, the optimal acreage decision will depend not only on expected profits, but also on higher moments of the profit distributions. In case of normally distributed returns, the expected utility criterion is completely specified by the expected value and variance of returns. Otherwise, it is a second-order Taylor series approximation to all risk averse utility functions.

The solution to (3) results in the irrigated acreage allocation equation. The optimal choice of $\vec{A}$ is a function of the following variables and their estimated parameters: expected profits for each crop, $\vec{\pi}$, the variance and covariance of these profits, and total irrigated acres A_y available

(4) $\quad A_i^* = A(\vec{\pi}_j, \sigma_{jj}, \sigma_{jk}, A_y), \ \forall\ i, j, k = 1, \ldots, n, j > k,$

where σ_{jj} denotes the variance in profit of the j^{th} crop and σ_{jk} the covariance of profit between the j^{th} and k^{th} crop. The covariance between any two crops, j and k, is included to account for the mechanism of risk-spreading by farmers via the portfolio effect.

The acreage response model (4) may be decomposed into two parts:
the substitution and expansion effects. In making decisions about irrigated acreage allocations, producers may compare the first and second moments of profits of alternative crops. Comparison of expected per-acre profits, and the variance and covariances of recent profits of alternate crops, are assumed to drive the substitution among crops for expected utility maximizing producers.

On the other hand, substitutions between irrigated crops have been accompanied by an overall increase in irrigated acreage over time. Changes in irrigation technology, costs of irrigation, irrigation policy, lender practices relative to irrigation and producer’s assessments of future economic conditions in agriculture all may stimulate chances in total irrigated acreage. These causes of chances in total irrigated acreage are partly or wholly independent of year to year variations in relative expected prices, yields, and costs of crops. Specifically, even if relative expected profits of crops remain constant, changes in total irrigated acreage may yield changes in the acreage allocation of crops. These impacts, representing an expansion effect, are captured by the parameters of the total irrigated acreage variable included in each acreage equation.

Application

This acreage response model (4) is applied to a 31-county region in Georgia which approximates the Flint River Basin. These counties, contain a representative crop mix for the state and in 1995 consumed approximately 51% of the state's irrigated water. Based on (4), an agricultural-water demand model for the principal Georgia crops (corn, cotton, peanuts and soybean) by county was developed. Developing such a model required estimating crop irrigated acreage response based on physical, economic and institutional determinants. These estimates of crop acreage by county were then applied to the BC formula for estimating water demand.

With regards to acreage and yield data, there are two major data sources for the analysis, University of Georgia - Cooperative Extension Service (UGA-CES) and the U.S. Department of Agriculture - National Agricultural Statistic Service (USDA-NASS). The state and county acreage irrigation data came from the UGA-CES. A subset of these data is the state irrigated acreage of the i^{th} crop at time period t, which includes all commodity and recreational irrigation groups. Data interpolation for the missing values assumed irrigation acreage increases or decreases linearly between two time intervals. This resulted in a time series of irrigated acreage by crop by county from 1970 through 1998. All harvest data are from NASS. These data are available for 1970 through 1998 and were downloaded from the USDA - NASS web-site http://www.usda.gov/nass/. The data contain the commodity harvested acreage by year for each county.

A major contribution of this analysis is accounting for the influence of economic variables on water demand. Incorporating the profitability of competing crops requires information on prices and costs for a given crop. Data on seasonal average price for a crop were collected from 1970 through 1999 editions of *Georgia Agricultural Facts*, published annually by USDA-NASS. Yield data were collected for each of the counties from *Georgia Agricultural Facts*. Yield enters the empirical model on a county basis to account for cross-sectional heterogeneity in terms of irrigated acreage. Government prices were proxied by the loan rate and target price. Prices for peanuts and soybean do not have a target price and are, therefore, proxied using the loan rate. For corn and cotton, annual government prices were defined as the maximum of the loan rate versus the target price. These data were collected from 1970-99 editions of the Agricultural Statistics published by USDA-NASS. Acreage restrictions for constructing government prices are not considered. Producers typically set aside marginal dryland to qualify for participation in government programs, and this study's goal is to examine acreage response for irrigated acres.

Variable cost of production data were collected from the USDA - Economic Research Service (USDA-ERS). The variable cost data are "historical," based on the actual costs incurred by producers in the southeastern U.S. during each year. These cost figures differ from the projection-based budgets put forth by land-grant universities to assist producers in planning. These actual measures of costs incurred are more relevant to the present analysis in considering profitability of competing enterprises. Data were downloaded from the following ERS website: http://www.ers.usda.gov/briefing/farmincome/costsandreturns.htm.

Generally, a producer's revenue per unit of output i in year t will be the higher of the government price and the market price for that output (Shumway). Although the government price for a given commodity should be known to producers before planting decisions are made, the market prices for crops to be planted will not be known in advance. Operators' planting decisions will therefore have to be based on expected revenue per unit.

The ex post producers' price for crop i in year t is designated as the supply inducing price, which is the maximum of either the government price or the seasonal average price for the crop. Expected supply inducing prices for producers making cropping decisions for period t were assumed to be a linear function of the announced government price for year t, the lagged supply inducing price and a time trend.

The second component of expected profits is expected yield. Expected yield may be estimated by regressing yield on lagged yield and a time trend. Duffy *et al.* suggest that deriving expected yield in this manner is preferable to a regression solely on a time trend. The trend variable in estimating yield allows for changes in production and irrigation technology.

The expression for expected profit per acre for crop i in county y at time t, $E_{t-1}(\bar{\pi}_{iyt})$, is defined as

$$E_{t-1}(\pi_{iyt}) = E_{t-1}(p_{it}Y_{iyt}) - c_{it},$$

where p_{it} is the supply inducing price for crop i at time t, Y_{iyt} is yield for crop i in county y at time t and c_{it} is the total variable cost for crop i at time t. Given covariance between yields and prices (Bohrnstedt and Goldberger), expected profits are calculated using

$$E_{t-1}(\pi_{iyt}) = E_{t-1}(p_{it})E_{t-1}(Y_{iyt}) + Cov(p_i, Y_{iy}) - c_{it},$$

where $Cov(p_i, Y_{iy})$ is the covariance between price and yield of the i^{th} crop in county y.

As indicated in (4), variances in profits for the crops were included for capturing the risk aversion of producers. The variance associated with profit for the i^{th} crop, σ_{ii}, is determined by the three-year period preceding year t (Chavas and Holt). Employing variance directly in the estimation has a limitation of the variable increasing for a random variable with an upward trend even though its relative risk (variance standardized by the mean) may not be increasing. Employing the coefficient of variation eliminates this scaling effect. Similarly, the covariances are calculated using the three-year period preceding year t and are standardized for eliminating the trend effect (Tareen).

Data summary statistics for the data and explanatory variables are presented in table 1. The irrigated acreage span a large range. One possible explanation of the large range is the time period of the data. Relative to the early 1970's there was rapid adoption of irrigation technology in the late 1970s through 1980s. Adoption was primarily driven by credit agencies requiring producers to irrigate a proportion of their land to minimize the downside risk associated with poor yields.

Econometric Model

Given the hypothesis of expected utility maximization and the functional relationship between the optimal irrigated acreage and components of expected utility in (4), the empirical model for optimal irrigated acreage equations is derived as

$$(5) \qquad A^*_{iyt} = \alpha_0 + \sum_{j=1}^{4} \beta_j \pi_{jyt} + \sum_{j=1}^{4} \theta_j \sigma_{jjyt} + \sum_{j=1}^{4} \sum_{\substack{k=1 \\ k>j}}^{4} \delta_{jk} \sigma_{jkyt} + \eta_i A_{yt} + \sum_{y=1}^{18} \theta_y D_y + \varepsilon_{iyt}, \text{ for } i = 1, \ldots, 4,$$

where A^*_{iyt} and π_{iyt} are the number of irrigated acres planted and expected profit per acre, respectively, of the i^{th} crop in the y^{th} county at time t. The expected per-acre profits are included to capture the substitutability in the crops. Variable σ_{jjyt} is the variance of profit for the j^{th} crop in the y^{th} county at time t, and is included to account for producer's risk responsiveness. Variable σ_{jkyt} is the covariance of profit between the j^{th} and k^{th} crop at time t, and is included to capture the portfolio effect relation between the crops. Both σ_{jjyt} and σ_{jkyt} are standardized for eliminating the scale effect. The total irrigated acres in the y^{th} county at time t, A_{yt} is included for capturing the expansion effect in irrigated acreage responsiveness. Dummy variable D_y is a county specific dummy variable accounting for cross sectional heterogeneity in the data. A county specific intercept shifting dummy allows for differences in mean irrigated acreage of the four crops across the counties. The last term, ε_{iyt}, is the error term associated with the i^{th} crop in the y^{th} county at time t. Parameters to be estimated from the data are α_0, β_j, β_j, δ_{jk}, η_i and θ_y.

In order to capture the differences among counties (including differences in size, soil, climate and economic conditions) in the Flint River Basin, dummy variables for 18 Lower Flint counties are compared against the aggregate of the remaining counties. The aggregated counties represent counties with very small irrigated acres of each crop.

Hypothesized relationships between irrigated acreage of a crop and each of the variables in (4) are based on economic theory and agronomic relationships (rotational considerations) between the crops. The expected signs on estimated regression coefficients are summarized in table 2.

The expected utility function of a risk averse producer in a competitive setting is concave. In the model context, concavity of the expected utility function implies that it is a monotonically increasing function of own profits. Hence, a positive sign is expected on the coefficient associated with profits for the i^{th} crop. Risk aversion implies expected utility will be a decreasing function of variance in the profit of the i^{th} crop. Therefore, an inverse relationship is hypothesized between irrigated acres committed to the i^{th} crop and variance in own profits.

In an allocation model, crops may have a substitute, complementary or no relationship at all. If two crops are substitutes to each other, then they are expected to be negatively related to each other in the producer's acreage allocation decision. Increasing profitability in a competing crop, say the j^{th} crop, is expected to lower acreage commitments for crop i. On the contrary, rising profits in the i^{th} crop may result in rising levels of acreage committed to the j^{th} crop that serves as a rotation crop.

With regard to variation in the profit of an alternative crop, say j, it is expected that rising variability in crop j's profit will influence irrigated acreage in the i^{th} crop in a manner similar to profitability of the competing crop. However, the expected relationship reverses. Rising variability of a substitute crop will likely increase acreage committed to the i^{th} crop, and rising variability of a complementary crop will tend to decrease irrigated acres in the i^{th} crop.

A negative correlation between two crops in a producer's portfolio reduces the farmer's risk. Thus, it is expected, in the equation for the i^{th} crop, there will be a negative sign associated with the covariance variable. However, in the same equation, comparing the covariance between other non-i crops, a reduced risk scenario suggests taking irrigated acres out of the production for the i^{th} crop and committing them to some combination the other two crops. A positive relationship is the expected sign in this case.

Estimation Results

Assuming the error terms are independent and identically distributed allows estimating (5) by ordinary least squares. All four equations (cotton, peanuts, corn and soybean) each with 398 observations are specified as functions of an intercept term, profits, variance and covariance of profits for each crop, the total irrigated acreage by county and county-specific dummy variables. Parameter estimates for each crop are presented in tables 3 through 6 with the estimates of the dummy variables reported in Tareen.

The F-test statistic in all acreage equations is significantly different from zero at the 1% level. This suggests a strong rejection of the null hypothesis that all parameters except the intercept are zero. The coefficients of determination, R^2, for the cotton, peanuts, corn and soybean equations are 0.68, 0.95, 0.81 and 0.64, respectively.

Profits of cotton are positively related to the irrigated acres of cotton (table 3). This relationship is statistically significant at the 1% level. Cotton responsiveness to its profitability, as measured through elasticity at the means, is 0.62. This measure of elasticity suggests for every 1% increase in the expected profits, irrigated cotton acreage will increase by over 0.60 %. As hypothesized, cotton profit has an inverse relationship in the corn and soybean equations. Cotton has higher cross profit elasticity in the soybean equation (-0.99) relative to the corn equation (-0.26). Both corn and soybeans are rotation crops for cotton, however, a higher elasticity for soybean may be explained by the marginal nature of soybeans in Georgia agriculture.

As listed in table 4, the peanut model is strongly driven by the profit potential in the peanut market. The coefficient associated with own profits in peanuts is significantly different from zero at the 1% level. A lower elasticity figure of 0.32 is indicative of the constraining role of government poundage quota on peanuts. Producers of quota peanuts do not have the flexibility to adjust their acreage in response to the changes in profitability. This study considers the quota prices and, therefore, total acreage adjustment in peanuts is not readily expected. The producers with quota provisions would commit acreage to ascertain meeting the quota poundage and would entertain other crops only for their rotation considerations. This is evident by the positive and significant coefficients associated with cross profitability of corn and soybean, both are rotation crops for peanuts. Cross profit of peanut in relation to corn, cotton and soybean are significantly different from zero at the 5%, 1% and 1% level, respectively. This demonstrates the hypothesized economic relationship in all instances except in the soybean equation. The complementary (crop rotation) relationship between peanuts and soybean may explain this positive relation. An increase in the profit of peanuts is complemented by a greater irrigated acreage commitment to soybeans in terms of rotation.

The coefficient for profit of corn has the counter hypothesized sign in table 5 and is significantly different from zero at the 5% level. This coefficient suggests there is an inverse relationship between profit from corn and irrigated acres of corn. However, this relation is not strong as evidenced by a low estimate of elasticity, -0.189. A possible explanation for this unanticipated sign is the minor role of corn in Georgia agricultural. It is grown primarily for its rotational considerations. Corn is rotated with cotton and peanuts given its nematode resistant properties. The decision to commit irrigated acres of land into corn may be driven less by profit consideration and more due to rotational consideration. Also, corn has been the least loss yielding crop among perceived alternatives for rotation. This counter hypothesized sign for the profit of corn repeats itself in the models for cotton and peanuts with statistical significance in both cases. However, in the soybean equation, another rotational crop in Georgia, profit from corn appear with the hypothesized sign, suggesting a competitive relationship with soybeans for irrigated acres of a rotational crop.

Soybean profits have the hypothesized sign and are significantly different from zero at the 1% level in table 6. The elasticity estimate for soybean profit is 1.3, suggesting soybean acreage is very responsive to changes in the profit of soybeans. These strong values suggest the choice of corn-soybean rotation may partly be driven by profit in soybeans in addition to the agronomic rotational considerations. Cross revenue effects of soybean profit are significant, at the 1% level, in all three equations. A cross-revenue elasticity of soybeans estimated at -2.91 in the cotton equation suggests a reduction of 3% in irrigated cotton acres for a 1% increase in the profit of soybeans.

Estimated coefficients of the variation for profit are not significantly different from zero at even a 10% level of significance for any crops with the exception of corn and peanuts in the soybean equation (table 6). Lack of statistical significance on the estimated coefficients of the variation suggests Georgia producers are not risk averse with respect to profit. Government price supports enable producers to consider only the expected mean of profits in making acreage allocation decisions.

Parameters associated with covariance between crops, hypothesized to capture the risk-spreading behavior of the producers, are significantly different from zero in half the instances. The covariance between corn and soybean is significant at the 10% level in the corn equation. The inverse relationship suggests the portfolio effect between the two crops. The covariance between cotton and soybean is significantly different from zero at 10% level in the soybean equation also suggesting the hypothesized portfolio effect.

The parameter estimate associated with total irrigated acreage in a county, A_{yt}, has the expected positive sign and is significantly different from zero at the 1% level in the cotton, peanut and corn equations and at the 5% level in the soybean equation. In terms of elasticity, cotton irrigated acreage is highly responsive to changes in the total irrigated acreage in a county. A coefficient estimate of 0.32 in the cotton equation suggests that a one acre increase in the total irrigated acreage results in approximately a one-third acre increase in cotton. Peanut acres are estimated to increase about one quarter of an acre for a one acre increase in total irrigated acres. Parameters associated with total irrigated acreage for corn and soybean equations are 0.08 and 0.04 acres, respectively.

Slippage

Changes in water demand are driven by changes in the distribution of crops producers choose to irrigate from year to year. These changes in crop distribution are in turn affected by their expected profitability and total available irrigated acreage. Conventional physical models do not consider the substitution and expansion effects in determining agricultural water demand. In contrast, the econometric model considers these effects. The difference in the estimates of water demand is slippage. This slippage may result in a higher or lower expected water use depending on the effect of relative profitability.

Slippage is measured by comparing the reduction in estimates of water demand, resulting from restrictions on total irrigated acreage available in a county, based on the physical model versus the econometric estimates of (5). The physical model computations of changes in water demand are calculated on a county basis. First, the crop distribution is calculated by dividing irrigated acreage of each of the four crops in a county by the total irrigated acreage in the county. Second, the calculated weights are multiplied by the reduction in total irrigated acreage in a county in 2001. Third, the weighted reduction in acreage is multiplied by the region-specific BC coefficient. Finally, the changes in water demand in the four crops are summed up over the counties to give the total 2001 decrease in water demand. The physical calculations of crop distribution are summarized in table 7.

The expected profits and yields are calculated by applying the coefficients from the estimated econometric model (5) to data for years 2000 and 2001. Data years 2000 and 2001 were obtained from the same data sources used in data collection for the econometric model. While data on market and government prices were available from the sources, cost and yield used in forecasting maintain the same assumptions as in the estimation of (5). Yield data for 2000 and 2001 are assumed to remain constant at the average level of 1994 through 1998. Variable cost data are extrapolated using the 1999 level of variable cost. The cost series is adjusted for inflation by the average cost index for the years 1994 through 1998.

Econometric forecasts for corn, cotton, peanut and soybean irrigated acreage in 2000 and 2001 combined are 690,120 acres (table 7). Under the econometric technique, a change in price results in altering the distribution of the crop mix. Changes in irrigated acres and the crop distribution are listed in table 7. The model estimate of 33,775 acres is only 2.3% higher than the actual reduction in acreage. The change in irrigated acreage and crop distributions estimates are used in conjunction with the BC coefficients to estimate slippage. Assuming a normal weather year, the slippage estimate is calculated in table 8.

In disregarding price effects, the physical model implicitly assumes the irrigated crop distribution remains constant between 2000 and 2001. On the other hand, the econometric model allows an adjustment in acreage distribution to reflect the role of expected profits, risk aversion and total irrigated acreage in a producer's irrigated acreage allocation decision. The differences in techniques result in a slippage amount of approximately 13%. This amount of slippage states the physical technique over-predicts water savings by approximately 16.9 million gallons per day. Thus, failure to consider the economic substitution and expansion effects has lead to erroneous policy analysis.

Conclusion

Incorporating price effects in the acreage allocation decision leads to slippage in the measurement of water demand. This study has attempted to identify the presence of slippage and the pitfalls associated with disregarding it in measuring changes in water demand. Considering slippage is a first attempt in determining the effectiveness of water conserving initiatives such as the Flint River Drought Protection Act. Currently, policy makers are assuming a certain level of decrease in irrigation water demand as a result of reducing the total irrigated acreage. The decrease in water demand is then in turn assumed to benefit both the interstate and intrastate allocation of water from the Flint River. The policy makers indicate increased water flows will result for Alabama and Florida as well as more water for the competing users within the state. In considering the dynamic price effects in acreage allocation, policy makers may be better equipped to assess the net change in water demand. Greater precision in information is beneficial given a smaller than expected reduction in water demand implies increased government expenditures on payments to farmers to not irrigate in auctions such as the one used in the FRDPA.

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Table 1. Summary Statistics: Data and Explanatory Variables

Variables	n[a]	Mean	Standard Deviation	Minimum	Maximum
Corn					
Irrigated Acres	475	6,691.99	5,125.80	77.81	27,895.06
Price	456	2.71	0.43	1.73	3.17
Yield	456	87.39	22.83	40.49	135.66
Cost	475	120.44	45.12	44.36	196.45
Profit					
Mean	456	131.89	50.90	27.93	246.20
Variance	418	21.73	26.08	0.03	239.86
Cotton					
Irrigated Acres	475	4,005.38	6,391.95	0	36,201.20
Price	456	0.67	0.11	0.41	0.77
Yield	456	597.78	143.50	317.25	830.86
Cost	475	234.50	83.93	82.57	344.79
Profit					
Mean	456	184.56	75.42	31.18	340.39
Variance	418	225.63	3,538.52	-1,544.43	72,335.93
Peanut					
Irrigated Acres	475	7311.72	5553.28	92.79	25,292.97
Price	456	0.27	0.07	0.14	0.35
Yield	456	2,820.22	243.83	1,987.92	3,344.06
Cost	475	275.34	97.73	101.30	434.15
Profit					
Mean	456	463.57	107.43	235.18	701.49
Variance	418	23.66	29.55	0.04	159.81

Table 1. Continued

Variables	n[a]	Mean	Standard Deviation	Minimum	Maximum
Soybean					
Irrigated Acres	475	2,135.63	2,273.51	0	12,939.66
Price	456	5.63	0.76	2.93	6.36
Yield	456	24.35	1.82	20.48	29.52
Cost	475	68.73	27.95	23.86	113.71
Profit					
Mean	456	67.48	16.29	24.53	97.93
Variance	418	14.82	23.56	-282.67	158.81
Cov Corn-Cotton	399	676.37	1,968.22	-10,005.96	7,992.90
Cov Corn-Peanut	399	969.45	2,144.73	-4,523.65	10,376.71
Cov Corn-Soybean	399	379.28	583.06	-2,093.99	2,430.93
Cov Cotton-Peanut	399	3,169.37	7,097.04	-16,584.60	34,782.35
Cov Cotton-Soybean	399	335.65	1,360.24	-4,929.09	7,046.16
Cov Peanut-Soybean	399	873.50	1,519.12	-3,103.32	7,024.04
Total Irrigated Acres	475	28,118.37	19,613.47	316	92,508

[a] n represents the number of observations in the 19 county region over 25 years. Fewer observations for some variables result from lags used in generating the variables.

Table 2. Expected Directional Impact of a Crop's Irrigated Acreage

Variable	Expected Direction of Irrigated Acreage for the i^{th} Crop[a]	
	Economic Theory	Agronomic
Profit		
Expected, i^{th} crop (π_{iyt})	+	
Expected, j^{th} crop (π_{jyt})	-	-, if substitute crop +, if rotation crop
Variance, i^{th} crop (σ_{iiyt})	-	
Variance, j^{th} crop (σ_{jjyt})	+	+, if substitute crop -, if rotation crop
Covariance, i^{th} and j^{th} crop (σ_{ijyt})	-	
Covariance, j^{th} and k^{th} crop (σ_{jkyt})	+	
Total Irrigated Acres (A_{yt})	+	

[a] i^{th} crop refers to the crop associated with the dependent variable and j^{th} and k^{th} crops refer to the remaining three crops.

Table 3. Estimated Cotton Irrigated Acreage Model and Elasticities at the Means

Variable	Parameter Estimate	Standard Error	Elasticity
Intercept	8,433.48*	1,934.58	
Cotton			
Profits			
Mean	13.39*	5.05	0.62
Variance[a]	0.01	0.06	0.0005
Corn			
Profits			
Mean	23.71*	8.07	0.78
Variance[a]	11.92	10.38	0.06
Peanut			
Profits			
Mean	-9.01*	3.42	-1.04
Variance[a]	-10.24	9.99	-0.06
Soybean			
Profits			
Mean	-172.65*	16.63	-2.91
Variance[a]	-6.99	9.75	-0.02
Covariance[a]			
Corn-Cotton	-0.10	0.15	-0.02
Corn-Peanut	-0.10*	0.15	-0.02
Corn-Soybean	1.38	0.44	0.13
Cotton-Peanut	-0.03	0.04	-0.02
Cotton-Soybean	0.75*	0.22	0.06
Peanut-Soybean	-0.73*	0.22	-0.16
Total Irrigated Acres	0.32*	0.04	2.28
F-value		23.14*	
Mean square error		3,990.15	
R^2		0.68	

*** significantly different from zero at the 10% level.

** significantly different from zero at the 5% level.

* significantly different from zero at the 1% level.

[a] Measured as coefficient of variation

Table 4. Estimated Peanut Irrigated Acreage Model and Elasticities at the Means

Variable	Parameter Estimate	Standard Error	Elasticity
Intercept	-5,151.94*	602.14	
Peanut			
Profits			
Mean	5.11*	1.06	0.32
Variance[a]	2.54	3.11	0.01
Corn			
Profits			
Mean	6.64*	2.51	0.12
Variance[a]	-1.83	3.23	-0.005
Cotton			
Profits			
Mean	0.69	1.57	0.02
Variance[a]	-0.01	0.09	-0.0003
Soybean			
Profits			
Mean	36.42*	5.18	0.34
Variance[a]	2.02	3.03	0.004
Covariance[a]			
Corn-Cotton	-0.02	0.05	-0.002
Corn-Peanut	0.02	0.05	0.002
Corn-Soybean	-0.13	0.14	-0.01
Cotton-Peanut	0.02**	0.01	0.01
Cotton-Soybean	-0.25*	0.07	-0.01
Peanut-Soybean	0.25*	0.07	0.03
Total Irrigated Acres	0.24*	0.01	0.94
F-value		211.76*	
Mean square error		1,241.932	
R^2		0.95	

*** significantly different from zero at the 10% level.

** significantly different from zero at the 5% level.

* significantly different from zero at the 1% level.

[a] Measured as coefficient of variation

Table 5. Estimated Corn Irrigated Acreage Model and Elasticities at the Means

Variable	Parameter Estimate	Standard Error	Elasticity
Intercept	1,236.32	1,127.55	
Corn			
Profits			
Mean	-9.53**	4.70	-0.19
Variance[a]	2.52	6.05	0.01
Cotton			
Profits			
Mean	-9.36*	2.95	-0.26
Variance[a]	0.001	0.03	0.00004
Peanut			
Profits			
Mean	-4.87**	1.99	-0.34
Variance[a]	-2.48	5.82	-0.01
Soybean			
Profits			
Mean	87.88*	9.70	0.89
Variance[a]	0.70	5.68	0.001
Covariance[a]			
Corn-Cotton	0.07	0.09	0.01
Corn-Peanut	-0.01	0.09	-0.002
Corn-Soybean	-0.47***	0.25	-0.03
Cotton-Peanut	0.03	0.02	0.01
Cotton-Soybean	-0.36*	0.13	-0.02
Peanut-Soybean	0.21	0.13	0.03
Total Irrigated Acres	0.08*	0.02	0.32
F-value		47.21*	
Mean square error		2,325.623	
R^2		0.81	

*** significantly different from zero at the 10% level.
** significantly different from zero at the 5% level.
* significantly different from zero at the 1% level.
[a] Measured as coefficient of variation

Table 6. Estimated Soybean Irrigated Acreage Model and Elasticities at the Means

Variable	Parameter Estimate	Standard Error	Elasticity
Intercept	-1,246.26***	699.67	
Soybean			
Profits			
Mean	40.50*	6.02	1.28
Variance[a]	-3.55	3.52	-0.02
Corn			
Profits			
Mean	-9.44*	2.92	-0.58
Variance[a]	-8.37*	3.75	-0.08
Cotton			
Profits			
Mean	-11.42*	1.83	-0.99
Variance[a]	-0.0002	0.02	-0.00002
Peanut			
Profits			
Mean	4.47*	1.24	0.97
Variance[a]	10.41*	3.61	0.11
Covariance[a]			
Corn-Cotton	0.02	0.05	0.007
Corn-Peanut	-0.07	0.05	-0.03
Corn-Soybean	0.17	0.16	0.03
Cotton-Peanut	0.01	0.01	0.02
Cotton-Soybean	-0.14***	0.08	-0.02
Peanut-Soybean	0.14***	0.08	0.06
Total Irrigated Acres	0.04**	0.01	0.49
F-value	20.02*		
Mean square error	1,443.11		
R^2	0.64		

*** significantly different from zero at the 10% level.

** significantly different from zero at the 5% level.

* significantly different from zero at the 1% level.

[a] Measured as coefficient of variation

Table 7. Physical and Econometric Estimates of Crop Distribution and Change in Total Irrigated Acres 2000 - 2001

Crop	Irrigated Acreage			Crop Distribution[b]	
	2000	2001[a]			
		Physical	Econometric	Physical	Econometric
Corn	216,851	210,376 (-6,475)[a]	216,070 (-781)	0.299	0.313
Cotton	227,952	214,653 (-13,299)	218,073 (-9,879)	0.314	0.316
Peanuts	175,383	165,704 (-9,679)	159,973 (-15,410)	0.242	0.232
Soybeans	93,015	88,604 (-4,411)	85,310 (-7,705)	0.128	0.124
Total	724,781	679,337	690,120 (-33,864)		

[a] Numbers in parentheses are the difference in 2001 and 2000 irrigated acreage.

[b] Crop Distribution = Irrigated $\text{Acres}_{i, y, 2000}$ / Total Irrigated $\text{Acres}_{i, y, 2000}$. i = corn, cotton, peanut and soybeans; y = counties in study area.

Table 8. Slippage in Measuring Change in Water Demand 2000 - 2001[a]

	Net Change in	BC	Decrease in Water Demand (acre-feet)[c]		
Crop	Acres	Coefficient[b].	Physical	Econometric	Slippage[d]
Corn	-781	11.20	-72,515	-8,744	
Cotton	-9,879	11.77	-156,524	-116,242	
Peanuts	-15,410	6.37	-61,655	-98,103	
Soybean	-7,705	7.59	-33,478	-58,518	
Total	-33,775		-324,172	-281,607	0.131

[a] Slippage measure assumes a normal weather year.

[b] Blaney-Criddle (BC) formula.

[c] Physical water demand is calculated by multiplying the physical crop distribution in table 7 by the change in total irrigated acreage times the BC coefficient.

Econometric water demand is calculated by multiplying the change in total irrigated acreage times the BC coefficient.

Note, one acre foot equals 325,800 gallons.

[d] Slippage is equal to one minus the ratio of the econometric decrease to the physical decrease in total water demand