Irrigation Water Demand: A Meta Analysis of Price Elasticities

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Abstract:

Meta-regression models are estimated to investigate sources of variation in empirical estimates of the price elasticity of irrigation water demand. Elasticity estimates are drawn from mathematical programming, econometric and field experiment studies reported in the United States since 1963. Explanatory variables include method of analysis, water price, time-frame of analysis, farmers' adjustment options, type of data, and climate. Results indicate that the magnitudes of elasticity estimates are affected by the method of analysis. When separate regressions are performed for the estimates from each method, the price of water at which an elasticity is estimated as well as the time-frame of analysis are found to influence price elasticities.

Key words: irrigation water demand, meta analysis, price elasticity

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Introduction

Irrigation of agricultural crops has long accounted for 80-90% of total water withdrawals in the western United States. Growth in population and incomes is creating increasing demands for water in non-agricultural and often non-rural sectors. An important measure of the effectiveness of price incentives in facilitating water reallocations and, more generally, of the economic feasibility of transferring water from irrigated agriculture to other uses, is the price elasticity of the derived demand for irrigation water.

Analyses of irrigation water demand and its price-responsiveness have been presented in the literature since the early 1960s. Some authors find that farmers are very unresponsive to changes in the price of water. Therefore such authors commonly caution against the use of pricing policy to bring about reductions in irrigation water use, because large price increases would be necessary to achieve even relatively small reductions in water use, while incurring large negative effects on agricultural income and wealth. Other studies indicate a more elastic demand and conclude that pricing policy would be an effective instrument since it would provide the necessary incentives for farmers to adjust to rising prices by using irrigation water more efficiently. Despite the importance of knowing farmers' responsiveness to price changes for irrigation water, little systematic study has been carried out on the factors which may cause these differing findings.

Our research uses meta analysis to statistically investigate potential sources of variation in the available empirical estimates of the price elasticity of irrigation water demand. Since the 1980s, meta analysis has been applied in the medical and social sciences to summarize, evaluate and analyze empirical research. The method—in the form of meta-regression analysis—is increasingly being used by resource and environmental economists (for an overview, see Bateman and Jones, 2003). However, in the area of water resources meta analysis has so far been limited to the study of contingent value estimates of the value of improved groundwater quality (Boyle, Poe and Bergstrom), wetlands (Brouwer et al.), and price and income elasticities of residential water demand (Espey, Espey and Shaw; Dalhuisen et al.). We believe our research is the first effort of using meta analysis to assess the literature on the price elasticity of irrigation water demand, and to attempt to explain the wide study-to-study variation found among the findings.

After briefly reviewing the literature, we present variables hypothesized to influence elasticity estimates and then apply them in a simple meta regression model using data from studies reported in the United States since 1963.

Research on Irrigation Water Demand

Estimates of the demand function for irrigation water and its price elasticities have commonly been based on the use of mathematical programming, especially linear programming. The early studies (e.g. Moore and Hedges) often intended to show that the demand is more price responsive than generally believed, and that even for low prices it is not perfectly inelastic as the U.S. Bureau of Reclamation had claimed in the past. Later studies have constructed subregional or regional demand functions from models of representative farms, and commonly calculated responsiveness by either arc-elasticity estimates along the stepped demand curve or by calculating elasticities after fitting continuous regression equations to the parametric data. The results typically show either an inelastic estimate for the whole price range considered, or an inelastic estimate for the lower prices and a less inelastic or elastic estimate for the higher prices (Shumway).

During the 1970s and early 1980s estimates of irrigation water demands and their shape have also been developed with statistical crop-water production functions based on data from field crops experiments conducted at state experiment stations (Hexem and Heady, Ayer and Hoyt, Keller and Ayer). Demand functions were constructed using an output price and varying the cost of water. Elasticity estimates based on field experiments generally are relatively unresponsive to price changes.

Elasticities have also been estimated with econometric studies that use data of actual farmer behavior (Frank and Beattie; Nieswiadomy; Ogg and Gollehon; Moore, Gollehon and Carey). Estimates calculated with econometric methods relying on secondary data tend to be more inelastic than suggested by mathematical programming models, but in some cases they are also very elastic.

Overall, elasticity estimates vary widely—not only between studies with different methods of analysis but also among them. A number of variables influencing the shape of the demand function as well as elasticity estimates have been identified in the literature, but there has been little systematic study on how and to what extent these variables influence the estimates and the policy recommendations based on them.

Conceptual Framework

Studies on price elasticities of irrigation water demand distinguish themselves not only with regard to the particular methods they employ, but also with regard to the inclusion or exclusion of a wide range of factors as well as practical implementation issues, all of which may affect the elasticity estimates. Important independent variables hypothesized to influence elasticity estimates can be grouped under six categories. Some variables are based on microeconomic theory, while others are largely associated with data-based decisions with little guidance available in economic theory.

Method of Analysis. We would expect that estimates from mathematical programming studies generally tend to be more elastic than those from econometric studies and in particular from field experiment studies. Ogg and Gollehon reasoned that these differences may reflect in part differing assumptions underlying these models. Econometric models produce positive estimates based on historical observed behavior that often show little fluctuations in water prices, while mathematical programming models yield normative estimates based on both historical and synthetic data. The latter can be adapted to represent a wide range of scenarios, and model the responses to water and product prices for which no historical observations need to exist. In case of the studies based on experiment station data, part of the reason for their inelastic estimates is that while they model changes in water applications for each of a few selected crops, they do not permit changes in the crop mix or provide possibilities for substituting other inputs (e.g. labor) or alternative irrigation technologies.

Irrigation Water Price. Due to the definition of the elasticity concept in percentage terms, the price elasticity of demand is not necessarily the same everywhere along the demand curve. In case of a straight-line demand curve, for example, demand is elastic at higher prices and inelastic at lower prices.

Time-Frame of Analysis. The distinction between a long-run and a short-run time-frame of analysis relates to the degree of fixity of certain inputs. A long-established a priori expectation is that price elasticity of demand is likely to be more inelastic in the short-run when decisions are constrained by factors such as water use technologies, than in the longer-run when more adjustments are possible (Johnston).

Farmers' Adjustment Options. The inclusion of high-value crops is hypothesized to contribute to a less elastic estimate. With regard to other adjustment options available to farmers, one would expect that in the lower price ranges the higher the substitutability of other resources for water, the more elastic the response of farmers would be. In one of the early studies on irrigation water demand Hartman and Whittlesey already noted that the kind of adjustments farmers are allowed to make in the model in response to changes in water supply determines the value of additional water and thus the shape of the demand curve. This was confirmed in a more recent study that focused on the effect of varying on-farm adjustment possibilities to changes in water price (Scheierling, Young and Cardon).

Type of Data. Irrigation water demand studies may be based on field plot/farm data or regional data, and use primary or secondary data. There are no *a priori* expectations with regard to the effect of these data-based choices.

Climate. Levels of precipitation and temperature in a study region may affect elasticity estimates. Although there is no explicit guidance from the literature, one would assume that estimates would be less elastic in a locale with scarcer precipitation and higher temperature.

In summary, theory suggests that price elasticity estimates would be more elastic (higher in absolute terms), if they are based on mathematical programming, are calculated for a higher current price, are based on a long-run analysis, exclude high-value crops, and result from a model that incorporates many options for substituting other resources for water.

Data and Empirical Model

The analysis is based on a review of approximately 40 studies, published from 1963-2003 in a wide array of journals and other reports that use mathematical programming, field experiments, or econometric methods to address issues related to the irrigation water demand in the United States. (Studies based on alternative methods, such as computable general equilibrium, or from other countries were excluded because of their limited numbers.) Of these, 18 studies had empirical estimates of price elasticities, or estimates on the demand for irrigation water that allowed the calculation of elasticities, and provided sufficient information on the variables considered as relevant for explaining variation in the estimates. For those irrigation water demand studies that reported no explicit price elasticity estimates, arc elasticities were calculated assuming a 25% increase in the price of irrigation water given for the year of the data used in the study. Several studies showed results from multiple models distinguished according to different variables. Estimates resulting from the inclusion of very study-specific variables such as an intermediate time-frame of analysis or particular soil types and functional forms could not be included. A total of 53 price elasticity estimates were obtained. The estimates for irrigation water demand elasticities range from -0.002 to -1.97, with a mean of -0.51 and a median of -0.22 (figure 1). The studies included in the analysis as well as the number and range of useable estimates is shown in table 1. In total, there are eleven mathematical programming studies with 21 estimates, four econometric studies with 22 estimates, and three field experiment studies with 10 estimates.

The basic empirical hypothesis is that the variation in elasticity estimates reported in the literature arises from differences in the method of analysis, the theory underlying these analyses, and practical implementation issues. The meta regression model can be written as:

$$b_j = b + \sum_{k=1}^{K} a_k Z_{jk} + e_j \qquad (j = 1, 2, \ldots, N)$$

where b_j is the reported estimate of the price elasticity of irrigation water demand in the *j*th study, ß is the intercept term, the Z_{jk} terms are the variables that explain the variation in the elasticity estimates across studies, the a_k terms are the coefficients that reflect the impact of particular variables, and the e_j terms are the regression residuals (Stanley and Jarrell).

The absolute value of the price elasticity estimates is used as the dependent variable. The independent variables used to explain variation in the elasticity estimates are described in table 2. In line with the six categories hypothesized to be important, they include (a) econometric method, field experiment (with mathematical programming being the omitted category); (b) price of water; (c) long-run; (d) high value crops, change in irrigated acreage, change in crop mix, change in irrigation schedule, change in irrigation technology; (e) regional coverage, secondary data; and (f) a precipitation as well as a temperature variable. Most of these variables are qualitative. In addition, the variable "year" of the data was included to investigate whether irrigation water was growing more or less scarce over time. It can also represent changes in the availability of data and methodological advances over time (Smith and Kaoru). Considering that the studies cover a period of four decades, this may be a reasonable assumption.

For the variable "price of water" the analysis is based on the price (in $ per acre foot) that was prevalent in the irrigation region in the year of the data used in the study, deflated with the USDA index of prices paid (annual average) for items used for production (USDA). Most studies included in the analysis did not provide data on the climatic variables "precipitation" and "temperature". We therefore chose a representative city for each study region and used data on mean annual precipitation (in degrees F) and mean annual temperature (in inches) from the Interactive Climate Page of the NOAA-CIRES Climate Diagnostics Center.

Results

Results for several linear models are reported in tables 3 to 5. With the dependent variable being expressed as absolute value of the elasticity estimates, negative coefficient values imply a less elastic demand and positive values a more elastic demand. The numbers in parentheses are the t-ratios calculated with the OLS standard errors.

Table 3 shows coefficient estimates for the pooled 53 elasticity estimates from the 18 mathematical programming, field experiment and econometric studies. Model 1a includes all independent variables except two with perfect correlation to the variable “field experiment”. Two additional variables that are highly correlated with one of the variables representing method of analysis, are left out in Model 1b. Model 1c further excludes variables for which, in the redundant variables test, the null hypothesis that they all have zero coefficients could not be rejected with the F-statistic and the Log likelihood ratio at a 1% significance level. Highly correlated variables and statistically redundant variables are listed in table 6.

Regression results for Model 1c explain more than half of the variation in the elasticities, and the signs and magnitudes of the coefficients generally conform to a priori expectations. However, they suggest with a high statistical significance that econometric elasticity estimates are much more elastic than those from mathematical programming studies. An examination of the estimates based on econometric models reveals that, of the 22 estimates included in the analysis of econometric studies, 16 originate from just one study (Frank and Beattie) and all are elastic—in contrast to the remaining 6 estimates from other studies, all of which are inelastic.

To control for the elasticity findings of Frank and Beattie, an intercept dummy for this study with the identification number 3 was included in Models 2a and 2b. Model 2a excludes highly correlated variables, and Model 2b also the variables identified as redundant. The dummy variable has the expected positive sign, its magnitude is about the size of the average difference between the estimates of study no. 3 and the other econometric studies, and it is statistically significant at the 1% level. The results of Model 2b are in line with three expectations based on prior theory: (a) econometric studies, and especially field experiment studies, tend to yield less elastic estimates than mathematical programming studies; (b) elasticities calculated at higher water prices tends to be slightly more elastic; and (c) results from long-run studies tend to be more elastic than those from short-run studies.

A problem with the regression results when all the studies are pooled is the lack of sufficient evidence that the residuals, and hence the dependent variable, come from a normal distribution. (Based on the Jarque-Bera statistic the null hypothesis for normally distributed residuals is rejected.) To test the hypothesis that pooling the estimates from studies based on three different methods of analysis may not be appropriate, a chow breakpoint test was performed (Model 3). The results are in table 4. Based on both the F-statistic and the Log likelihood ratio, the null hypothesis of equivalence of the regressions based on mathematical programming, field experiment and econometric studies is rejected.

Separate regressions were then performed for the estimates from mathematical programming studies (Model 4), econometric studies (Model 5), and field experiments (Model 6). Table 5 presents results for each model for two cases: first without highly correlated variables, and then also without redundant variables. As expected, for all models the exclusion of redundant variables tends to increase the absolute values of the t-statistics of the remaining variables, and decrease the gap between coefficients of determination and adjusted coefficients of determination while leaving the levels of the coefficient of determination almost unchanged.

The results for the mathematical programming studies in Model 4b suggest that the variable "price of water" has the most important positive impact on the elasticity estimate, follo wed by "long-run". Results are similar for the econometric studies in Model 5b, except that the order of magnitude of the coefficients is much smaller, and the t-statistics are lower. For the case of the field experiment studies, results for Model 6b show a highly statistically significant coefficient for "price of water", with a magnitude about half the size of the water coefficient of the mathematical programming studies. (Since all field experiment studies take a short-run view, no coefficient for "long-run" could be calculated).

Overall, in the separate regressions the coefficients of determination tend to be relatively high (ranging from 0.74 for mathematical programming studies to 0.90 for econometric studies to 0.97 for field experiments), and are in every case higher than those for the pooled studies. For the mathematical programming and field experiment studies the null hypothesis for normally distributed residuals cannot be rejected (using the Jarque-Bera statistic), but it is rejected for the residuals of the econometric studies.

The climate variables do not perform as we hypothesized. The variable "temperature" seems to be redundant in most models, and the variable "precipitation" has in several models a small negative coefficient. This may be due to our simple procedure of choosing a representative city for each irrigation area, even when it covers a whole state (in the case of several states we averaged the data from representative cities of each state), or it may be due to particular sample issues such as lack of variation across observations.

Contrary to expectations, the inclusion of high-value crops in the crop mix seems to not have much impact on the elasticity estimates in any of the models. Part of the reason may be that few if any of the studies measure elasticity at a water price high enough to impact consumption by high-valued crops.

In several of the models the variable “year” is statistically significant, albeit with a very small magnitude. Pooling all the studies, more recent studies tend to have slightly more inelastic estimates. Since this is also the case for the separate result for the econometric studies, but not for the results of the mathematical programming and econometric studies (they suggest a very small positive coefficient), it is probably reasonable to assume that the Frank and Beattie study with data from the year 1979 is causing these outcomes.

Some interesting qualitative insights can be gained from the correlation analyses presented in table 6. At least in the sample included in our analysis, mathematical programming studies are usually based on secondary data and allow for a change in crop mix. They vary with regard to the inclusion of other adjustment options of farmers. Econometric studies rely on secondary, regional data. Because they are based on actual farm behavior, they implicitly include the whole range of adjustment options. By contrast, field experiment studies have been based on primary and usually field plot data. With their short-run time-frame of analysis, they do not consider possible changes in acreage, crop mix or irrigation technology, but scheduling changes are usually included.

Table 6 also shows the variables found to be redundant in the different model runs. A few times the climate variables are listed among them which, again, may be caused by sample issues or our procedure for generating the variables. Some of the options for farmers’ adjustments are also found to be redundant. In the case of mathematical programming studies, for example, the reason is mainly because these variables do not vary much from study to study (for instance, all studies except one allow for changes in irrigated acreage).

Conclusions

Based on our analysis of the causes of variation among price elasticitiy estimates of irrigation water demand, a number of inferences can be drawn. First, results from the pooled regression indicate that the method of analysis has a significant impact on price elasticity estimates. In particular, estimates based on the use of econometric methods are likely to result in much more elastic estimates. This is contrary to expectations, and is shown to be caused by an outlier study.

Second, when controlling for the outlier study, results from the pooled regression suggest that mathematical programming studies are likely to produce more elastic estimates than econometric studies and particularly more elastic estimates than studies based on field experiments. Also the price of irrigation water and a long-run time frame tend to cause more elastic estimates of price elasticities. These results are in line with prior theory.

Third, based on the chow test, the null hypothesis that the coefficients from separate regressions for mathematical programming, field experiment and econometric studies are identical is rejected.

Fourth, a separate regression for mathematical programming studies suggests that the price of irrigation water has a relatively large and significantly positive impact on price elasticity estimates. A separate regression for econometric studies suggests that a higher price of water and a long-run time-frame tend to lead to more elastic estimates, but the magnitude is much smaller than for mathematical programming studies. A separate regression for field experiment studies indicates that water price has a significantly positive impact on price elasticity estimates, but the impact is less than with mathematical programming studies, but larger than for econometric studies.

Fifth, the lack of a statistically significant impact of high-value crops may be due to the relatively low water prices prevalent in the study areas. The adjustment options available to farmers do not show to be statistically significant because they tend to either not vary at all among the studies of a particular method of analysis, or vary only in the case of a few studies.

And sixth, the result that the climate variables would have either no significant impact on price elasticity estimates or a small impact, but with an unexpected sign, may be caused by the approach for generating the climate data or by particular sample issues.

Overall, compared to other meta regression results, our analysis—although it is based on only a few independent variables—is able to explain a very high percentage of variation in the elasticity estimates, for the pooled studies and particularly after observations are separated by method of analysis.

We plan to pursue two avenues of further research. One is to try to understand why the outlier study yields results so much at variance with the remainder of the literature. The second is to explore the results of considering observations where the elasticity estimates are drawn from higher prices of irrigation water.

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Table 1: Irrigation Water Demand Elasticities

Author	Identification Number	Number of Estimates	Range of Estimates
Mathematical Programming Studies			
Moore, C.V. and Hedges (1963)	12	1	-0.07
Heady, Madsen, Nicol and Hargrove (1973)	5	1	-0.15
Shumway (1973)	18	1	-1.97
Kelso, Martin and Mack (1973)	11	8	-0.002 to -1.01
Moore, C.V., Snyder and Sun (1974)	13	1	-0.42
Hedges (1977)	6	1	-0.04
Gisser, Landford, Gorman, Creel and Evans (1979)	4	2	-0.10 to -0.12
Howitt, Watson and Adams (1980)	9	1	-0.97
Bernardo, Whittlesey, Saxton and Bassett (1987)	2	1	-0.12
Hooker and Alexander (1998)	8	1	-0.22
Scheierling, Young and Cardon (2003)	17	3	-0.02 to -0.16
Econometric Studies			
Frank and Beattie (1979)	3	16	-1.01 to -1.69
Nieswiadomy (1985)	15	1	-0.80
Ogg and Gollehon (1989)	16	1	-0.26
Moore, R.M., Gollehon and Carey (1994)	14	4	-0.03 to -0.10
Field Experiment Studies			
Hexem and Heady (1978)	7	4	-0.06 to -0.10
Ayer and Hoyt (1981)	1	3	-0.06 to -0.16
Kelley and Ayer (1982)	10	3	-0.04 to -0.56

Table 2. Description of Variables

Name	Mean	Definition of Variables
Method of Analysis		
Mathematical Programming		Omitted category for pooled studies
Econometric Method		Qualitative variable = 1 for econometric method, 0 for mathematical programming and field experiment
Field Experiment		Qualitative variable = 1 for field experiment, 0 for econometric method and mathematical programming
Irrigation Water Price		
Price of Water	2.58	\$/af (deflated with USDA Index of Prices Paid for Items Used for Production, 1910-14 = 100)
Time-Frame of Analysis		
Long-Run		Qualitative variable = 1 for a long-run, and 0 for a short-run time-frame of analysis
Farmers' Adjustment Options		
High Value Crops		Qualitative variable = 1 for inclusion of high value crops, and 0 otherwise
Change in Irrigated Acreage		Qualitative variable = 1 if irrigated acreage can be changed, and 0 otherwise
Change in Crop Mix		Qualitative variable = 1 if crop mix can be changed, and 0 otherwise
Change in Irrigation Schedule		Qualitative variable = 1 if irrigation scheduling can be changed, and 0 otherwise
Change in Irrigation Technology		Qualitative variable = 1 if irrigation technology can be changed, and 0 otherwise
Type of Data		
Regional Coverage		Qualitative variable = 1 for a region or state as a unit of study, and 0 for a field plot or farm
Secondary Data		Qualitative variable = 1 for use of secondary data, and 0 for use of primary data
Site Characteristics		
Precipitation	12.31	Mean annual precipitation in study area (inches)
Temperature	60.13	Mean annual temperature in study area (^{0}F)
Year		The year of the data used in the study

Table 3. Determinants of Price Elasticities of Irrigation Water Demand (Pooled Studies)

	Pooled Studies			Controlling for Study No. 3	
Independent Variable	Model 1a	Model 1b	Model 1c	Model 2a	Model 2b
Constant	50.81	45.05	43.22	15.88	20.00
	(3.76)	(3.46)	(3.78)	(1.18)	(1.72)
Method of Analysis					
Econometric Method	0.75***	0.48***	0.47***	0.05	-0.03
	(3.02)	(2.79)	(4.22)	(0.25)	(-0.18)
Field Experiment	-0.95*	-0.16	-0.12	-0.22	-0.22
	(-1.96)	(-0.73)	(-0.70)	(-1.17)	(-1.48)
Irrigation Water Price					
Price of Water	0.04	0.05	0.05	0.05*	0.05**
	(1.36)	(1.63)	(1.63)	(1.90)	(2.11)
Time-Frame of Analysis					
Long-Run	0.27*	0.19	0.19	0.15	0.13
	(1.99)	(1.56)	(1.56)	(1.39)	(1.32)
Farmers' Adjustment Options					
High Value Crops	-0.10	-0.03		-0.05	
	(-0.50)	(-0.19)		(-0.29)	
Change in Irrigated Acreage	-0.92				
	(-1.67)				
Change in Crop Mix					
Change in Irrigation Schedule	0.05	0.02		-0.09	
	(0.24)	(0.13)		(-0.53)	
Change in Irrigation Technology	-0.37				
	(-1.45)				
Type of Data					
Regional Coverage	-0.00				
	(-0.39)				
Secondary Data					
Climate					
Precipitation	-0.00	-0.01		-0.01	
	(-0.39)	(-0.61)		(-1.22)	
Temperature	-0.01	0.00		0.00	
	(-0.72)	(-0.28)		(0.21)	
Year	-0.03***	-0.02***	-0.02***	-0.01	-0.01*
	(-3.72)	(-3.46)	(-3.77)	(-1.17)	(-1.71)
Dummy for Study No. 3				0.73***	0.68***
				(3.96)	(3.94)
R^2	0.61	0.58	0.57	0.69	0.68
Adjusted R^2	0.50	0.49	0.53	0.62	0.64
Number of Observations	53	53	53	53	53

Note: t-statistics are in parentheses; * indicates significance at the 10% level; ** indicates significance at the 5% level; *** indicates significance at the 1% level.

Table 4. Stability of Coefficients across Methods of Analysis

Independent Variable	Pooled Studies Model 3
Constant	58.69
	(4.27)
Method of Analysis	
Econometric Method	
Field Experiment	
Irrigation Water Price	
Price of Water	0.06*
	(1.98)
Time-Frame of Analysis	
Long-Run	
Farmers' Adjustment Options	
High Value Crops	
Change in Irrigated Acreage	
Change in Crop Mix	
Change in Irrigation Schedule	
Change in Irrigation Technology	
Type of Data	
Regional Coverage	
Secondary Data	
Climate	
Precipitation	0.01
	(0.25)
Temperature	-0.02**
	(-2.41)
Year	-0.03***
	(-4.22)
R^2	0.37
Adjusted R^2	0.31
Number of Observations	53
Chow Breakpoint Test: 53	
F-Statistic 16.25	Probability 0.00
Log Likelihood Ratio 88.15	Probability 0.00

Note: t-statistics are in parentheses; * indicates significance at the 10% level; ** indicates significance at the 5% level; *** indicates significance at the 1% level.

Table 5. Determinants of Price Elasticities of Irrigation Water Demand (by Method of Analysis)

	Mathematical Programming Studies		Econometric Studies		Field Experiment Studies	
Independent Variable	Model 4a	Model 4b	Model 5a	Model 5b	Model 6a	Model 6b
Constant	-16.02	-25.15	107.94	107.98	-26.53	-26.87
	(-0.73)	(-1.85)	(11.36)	(11.70)	(-2.57)	(-3.35)
Irrigation Water Price						
Price of Water	0.32***	0.30***	0.02	0.02	0.16***	0.16***
	(5.00)	(6.07)	(0.94)	(0.99)	(6.80)	(13.11)
Time-Frame of Analysis						
Long-Run	0.37	0.21	0.04	0.04		
	(1.36)	(1.56)	(0.46)	(0.46)		
Farmers' Adjustment Options						
High Value Crops	0.13				-0.01	
	(0.34)				(-0.25)	
Change in Irrigated Acreage	-0.05					
	(-0.08)					
Change in Crop Mix						
Change in Irrigation Schedule	0.03					
	(0.17)					
Change in Irrigation Technology	-0.18					
	(-0.66)					
Type of Data						
Regional Coverage	-0.32					
	(-0.96)					
Secondary Data						
Climate						
Precipitation	-0.04	-0.04**	-0.02*	-0.02**	-0.00	
	(-1.34)	(-2.67)	(-2.00)	(-2.23)	(-0.37)	
Temperature	-0.00		0.00		-0.00	
	(-0.18)		(0.19)		(-0.58)	
Year	0.01	0.01*	-0.05	-0.05***	0.01*	0.01**
	(0.78)	(1.86)	(-11.29)	(-11.63)	(2.53)	(3.28)
R^2	0.79	0.74	0.91	0.90	0.97	0.97
Adjusted R^2	0.59	0.68	0.87	0.88	0.93	0.96
Number of Observations	21	21	22	22	10	10

Note: t-statistics are in parentheses; * indicates significance at the 10% level; ** indicates significance at the 5% level; *** indicates significance at the 1% level.

Table 6. Correlation Analysis (by Model)

Model	Correlated Variables*	Redundant Variables
Pooled Studies (Models 1 and 2)	*Field Experiment* with Change in Crop Mix Secondary Data Change in Irrigated Acreage with *Field Experiment* (-0.94) Change in Crop Mix (0.94) Secondary Data (0.94) Regional Coverage with *Field Experiment* (-0.84) Change in Crop Mix (0.84) Secondary Data (0.84) Regional Coverage with Change in Irrigated Acreage (0.89) *Econometric Method* with Change in Irrigation Technology (0.83)	High Value Crops Change in Irrigation Schedule Precipitation Temperature
Test of Stability of Coefficients (Model 3)	Econometric Method with Field Experiment (in all types of studies) Econometric Method with High Value Crops Regional Coverage Secondary Data (in econometric studies) Field Experiment with Long-Run Change in Irrigated Acreage Change in Irrigated Crops Change in Irrigation Schedule Change in Irrigated Technology Regional Coverage Secondary Data (in field experiment studies)	
Mathematical Programming Studies (Model 4)	Mathematical Programming (omitted variable) with Econometric Method Field Experiment Change in Crop Mix Secondary Data	High Value Crops Change in Irrigated Acreage Change in Irrigated Technology Regional Coverage Temperature

Table 6. Continued

Model	Correlated Variables*	Redundant Variables
Econometric Studies (Model 5)	Econometric Method with Field Experiment High Value Crops Change in Irrigated Acreage Change in Crop Mix Change in Irrigated Schedule Change in Irrigated Technology Regional Coverage Secondary Data	Temperature
Field Experiment Studies (Model 6)	Field Experiment with Econometric Method Long-Run Change in Irrigated Acreage Change in Crop Mix Change in Irrigation Schedule Change in Irrigation Technology Regional Coverage Secondary Data	High Value Crops Precipitation Temperature

* Perfect correlation if not indicated otherwise in parentheses.
Note: Variables in italic are used in the regression.

Figure 1. Distribution of Price Elasticities of Irrigation Water Demand