The Economics of Water: The Effects of Irrigation on Average Farm Revenue

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Abstract

By 2025, water withdrawals are expected to increase by 50% in developing countries and 18% in developed countries. By 2050, 2.7 billion people will need to draw from our current source of freshwater; irrigated agriculture currently accounts for 40% of all food production. With the demand for irrigation water rapidly increasing and supply being finite, issues related to conservation, allocation and policy are becoming more and more important. This investigation is aimed at analyzing production behavior through a study of average farm revenue and several input demand variables. It is found that farmers seek to maximize profit through increased water application rates as well as production of high -valued, water -intensive crops. Through an understanding of what drives production behavior, policy makers can increase their understanding of irrigation water importance as well as properly control its usage. Furthermore, by investigating water consumption in the largest water using sector (agricultural production), the world can come to a better understanding of the importance of irrigation in the agricultural industry as well as the impact of decreases in water availability on food production.

One of the greatest global issues facing the world today is water scarcity; in particular, freshwater allocation, facilitation and usage. This issue can be seen in places like the American West where drastic conservation practices and water policies have plagued states like California, Arizona and Washington. Despite continual drought, global warming and an ever increasing population, people continue to overuse water privileges. The future of our water supply is becoming more and more dependent on allocation rights, conservation methods and improved efficiency.

A particular case study of water usage in a drought stricken area is a reflection of many areas in the world. The problem of overpopulation coupled with limited resources is one that affects everyone, not just the United States. Increasing attention has been directed toward the problem of over consumption and the search to find economically viable solutions. An investigation aimed at determining the relationship between average revenue and multiple independent variables is performed. The purpose of this investigation is to provide insight into production behavior in the hopes of improving water allocation rights, policy and efficiency. In the history of man, water has never been worth so much as it is today; with its multiple usages, almost every economic sector relies on water in one way or another.

The economic research question being addressed is: How do several independent factors, including irrigation water application, crop types, county revenues and acres harvested, affect the average farm revenues of counties in Washington State? This analysis is aimed at investigating the relationship between average revenue and the quantity of irrigation water applied as well as crop types in a county based, multi-year model. I hope to use this model to complement the work of Yoder (2014) by modeling an economy where water application rates vary due to crop acreage and type, enabling some light to be shed on the factors that affect average farm revenue.

The purpose of this investigation is to fulfill two research objectives: determining the relationship between average farm revenue and the quantity of irrigation water applied, and determining the relationship between average farm revenue and crop types. Such objectives allow me to compare differences in revenue associated with changes in water quantities to shed light on the marginal benefits of irrigation water to various crops. Through this analysis, I hope to find a linkage between average farm revenues and irrigation water usage. The benefits of such research result in insight into farmer's behaviors (assuming income is a driving factor), investigation into the effects of inputs and policy types on farm revenue and the gathering of information that can be used for future crop forecasting. To mitigate the inevitable side effects of water wastage and reallocation on agriculture, this world must first understand what drives water usage through an analysis of farmer behavior.

Previous Literature

Economic research related to irrigation water usage and government policies ranges from the study of strategic behavior in water usage to the study of the effectiveness of technology-adopting incentive programs. Various studies are being conducted throughout the world using dozens of econometrics models and the resulting empirical analyses have varied. Most analyses have concluded that water value is highly dependent on a number of factors, and any disruption to current irrigation policies results in alternative problems. Because of such complications, a modern analysis of the direct effects of water quantity, coupled with various other inputs, is an arduous and often-times complicated task.

The principal body of work that my analysis aims to expand upon is that of Yoder (2014) in which he investigates the marginal values of various crops in six counties. Marginal value as defined by Gibbons (1986) is as follows: "The marginal value of water is the change in profit from applying an additional effective unit of water over some portion of the irrigated acreage. The value can belong in the long run or short run, and for mixed crops or a single crop." This knowledge aids in further analysis of my model in which average revenue is found in the long run. Gibbon's research indicates that in the long run, average revenue is equal to marginal revenue. This allows for my model to be compared to that of Yoder's (2014) and others who use marginal value analyses.

Yoder (2014) uses a short run, inverse demand equation assuming fixed-water inputs to determine the maximum value of water based on water allocation and policy. His focus is aimed at data from several counties within the Yakima Valley where the Yakima River Basin Integrated Water Resource Management Plan (IP) is currently being implemented and policy changes are occurring. A method called Four Accounts Analysis is used to model the relationship between curtailment and the value of agricultural production. The method shows that increased curtailment results in decreased marginal value of crops. My model does not incorporate fallowing; therefore, marginal value is solely dependent on the revenue generated by a given crop at different water application rates. Yoder's theoretical model of policy regimes opens up further analysis into both application rates and allocation schemes.

Whittlesey (2003) is another economist who has greatly contributed to the current body of knowledge concerning agricultural water usage, especially in Washington State. Many of his economic analyses concern farm responses to technology and irrigation cost changes; in particular, he studies responses to irrigation technology incentives. Whittlesey uses an irrigated farm model assuming 100% efficiency and profit maximization in his 2003 publication, "A Theoretical Analysis of Economic Incentive Policies Encouraging Agricultural Water Conservation," to measure, among other variables, the relationship between changes in water supplied and revenue. This model serves as a basis for both the setup of my production function as well as calculations having to do with irrigation acreage. The results of my analysis can be compared with the work of Whittlesey (2003) to add to existing knowledge related to the effects of water quantities on profit.

Bodisco (2007) uses several different models including a Cobb-Douglas production function and Heckscher-Ohlin trading model to analyze the value of water in agriculture throughout different regions in the United States. Such models shed light on the relationship between irrigation technologies and water values as well as serve as a basis of comparison between my findings and those of previous researchers. He finds that the Stolper-Samuelson theory is one of the most useful theories used in measuring water value; he hypothesizes that water values increase with an increase in price of water-intensive crops. I use the Stolper-Samuelson theory, coupled with the basic theory of input demand, to investigate the relationship between average revenue and orchard crops, which are water-intensive.

Moore (1994, 1999) has written several articles in which he analyzes the benefits of different models in water analysis, finding that in the short run, allocation decisions are based on crop acreage and exogenous variables such as input prices and climate. He uses a quadratic function composed of several crop input prices, output prices and water prices. Moore's work is relevant to my investigation of average revenue because it serves as a reference on important independent variables as well as an indicator of relevant alternative models.

My investigation of Washington State, analyzed through a production input demand model, aims to add to the current body of knowledge by investigating the impact of several independent variables on average farm revenue. I hope to shed light on what drives farm-based average revenue in the long run and thus develop a base model to further analyze the relationship between marginal value and supplied water quantities. My model also opens the door for further analyses on water pricing, allocation schemes, water policies and the effects of differences in efficiencies between irrigation technologies. My model is supported by economic and empirical theory; it provides a basis for further research related to many different avenues of irrigation water research. It also explains a proportion of the correlation between average revenue and multiple independent variables.

Theoretical Model

The research objective is to not only perform a regression of average farm revenue for an aggregated county-level model of Washington State, but to also analyze the relationship between such average revenues and various variables including the quantity of water applied in the long run. The relevant economic theory that is used to test my research objectives is the basic microeconomic production theory pertaining to perfectly competitive markets, applied using an inverse demand function and taking supply as given. This model is used to test empirical implications of diminishing marginal returns, varying elasticities and to derive inferences related to allocation schemes to determine the effects of irrigation on the marketplace.

Production theory states that competitive producers seek to maximize profit through production at a technologically feasible, optimal level taking input and output prices as given. Furthermore, such firms are price takers and technology is exogenously given (Levin 2004). The input demand equation states that quantity demanded is a function of input price, output price, alternative variable input price and fixed-input quantities. In this study, I am interested in the inverse input demand equation with output price written as a function of input quantity demanded, input prices, alternative variable input prices and fixed-input quantities.

The production theory of input demand is applied through the microeconomic theory of perfect competition which says that in the long run, the demand for a given good is perfectly elastic and price is a function of this demand, ceteris paribus. Furthermore, output levels are assumed to be at long run, perfect competitive equilibrium allowing for fixed-input quantities in my input demand equation. As a result, price is equal to average revenue which, as previously noted by Gibbons (1986), is equal to marginal revenue in the long run. This assumption is important for two reasons. First, it allows price to be equal to average revenue in a model of input demand in which average farm revenue is sought to be maximized in accordance with the theory of production. Secondly, the assumption that average revenue is equal to marginal revenue allows for comparison between my model and the current body of knowledge such as Yoder's (2014) research.

Furthermore, the theory underlying the law of input demand states that price is a function of quantity demanded; quantity demanded being equal to changes in both quantity demanded as well as typical demand shifters such as the price of substitutes and income. Holding the assumption that price is equal to average revenue true, then average revenue is a function of various independent input demand variables. Thus a sufficient model is developed that measures the relationship between average revenue (in this case, average farm revenue) and the various independent variables that typically reside in an input demand function. Applying this model to agricultural data indicates that variables such as fixed-input quantities, variable input prices, alternative crop prices and income all have an impact on the dependent variable, average revenue. Assuming all such independent variables are normal goods, each one is expected to exhibit a positive relationship with average farm revenue.

To answer my research objectives pertaining to the relationship between average farm revenue and quantity demanded as well as crop type, the theory of input demand must hold true. In accordance with this theory, an increase in the quantity demanded results in an increase in price. In this model, input demand is evaluated through the eyes of farmers who demand irrigation water to supply agricultural goods. Today, the demand for agricultural irrigation water is drastically increasing due to several speculated variables. As Yoder's (2014) research indicates, an increase in irrigated crop acreage as well as an increase in water-intensive crop acreage leads to an increase in demand for irrigation water. It is speculated that irrigation levels are highly correlated with farm revenue. Based on the theory of demand, such increases in irrigation water demanded lead to increases in agricultural prices and thus, increases in average revenue.

Empirical Model

According to the theory of perfect competition, average revenue is equal to marginal revenue and output price in the long run assuming constant returns to scale. This implication allows my demand model to be applied to those such as Yoder's (2014) and Whittlesey's (2003) work in which marginal revenue is determined and used to find the value of irrigation water. My model, such as previous researchers' models, holds the assumption that irrigators will not overwater, maximizing profit in the long run. Average revenue is assumed to be dependent on several independent quantity variables central to the production theory of input demand. The variables that I use as independents include the percentage of all land irrigated (Irr), percentage of irrigated land dedicated to orchard crop (Orch), percentage of irrigated land dedicated to vegetables (Veggies), and the quantity of water applied per acre (WperA).

To accomplish my research objectives, two independent variables are developed.
The independent variable that measures the total percentage of land irrigated in each county (Irr) represents the quantity of irrigation water demanded. Through an analysis of the relationship between the quantity of water demanded and average revenue, my first research objective is obtained.

The independent variable that measures the percentage of county acreage dedicated to orchard crop (Orch) represents the quantity demanded of high-revenue-generating crops. In relation to the production theory of input demand, this variable represents a fixed-input quantity. Such a variable allows the relationship between crop type and average revenue to be explored. It is hypothesized that both independent variables exhibit a positive relationship with the dependent variable, average revenue. Such hypotheses are supported by past research including that of both Whittlesey (2003) and Yoder (2014) in which high-revenue-generating crops as well as higher quantities of water exhibit positive correlations with crop prices.

Two additional independent variables are hypothesized to positively impact average revenue. The variable that represents the percentage of land dedicated to vegetable production in a given county (Veggies) is used to test the relationship between average revenue and the quantity demanded of an alternative good. This variable represents an alternative, fixed-input quantity. Current research done by Yoder (2014) indicates that the highest yielding crop division in the Yakima Valley is orchard production while the second highest is vegetable production. Logically this indicates that vegetable production is a substitute for orchard production and that both are normal goods. Yoder's (2014) research also indicates that a correlation exists between higher incomes and higher revenue-generating crops as well as income and increased irrigation water usage. This indicates that crop and water variables are normal goods.

Furthermore, the variable (WperA) representing the average irrigation water applied per acre in each county serves as another fixed-input quantity. Higher revenue-generating crops have higher water application rates; therefore, the amount of water applied per acre is an indication of the productivity of the land. The productivity of a farmer's land is believed to positively impact average farm revenue. Based on the production theory of input demand, the relationship between average revenue and the four specified independent variables is tested through an inverse demand regression. The Hausman test is used to determine the significance of using a fixed versus a random effects model. The data collected spans four years and multiple counties; the empirical model looks like such:

$$(1)\ lnAR = \beta_0 + ln\beta_1\, Qw + ln\beta_2 Orch + ln\beta_3 Veggies + ln\beta_4 WperA + \varepsilon_0$$

This regression is in log-log form, assuming constant elasticities across variables. Past research centered on farm-based revenues indicates that typically agricultural products exhibit diminishing marginal returns. Assuming this is true, the question becomes: Does the elasticity between crop and water quantities change as demand changes? To test elasticities, an alternative model in which non-constant elasticities are assumed is tested in the form of:

$$(2)\ AR = \beta_0 + \beta_1\, Qw + \beta_2 Orch + \beta_3 Veggies + \beta_4 WperA + \varepsilon_0$$

It is important to note that a primary independent variable, price, is omitted from both models. There are two reasons for this, the first being that there is a lack of data available on water price as well as individual crop price per county. Secondly, average revenue is computed by dividing the net sales of each given Washington State county by total acreage harvested in corresponding counties. Net sales are highly correlated with price, which may cause reverse causality if price were to be included as an independent variable. Because of the omission of price variables, it is assumed that the quantities of inputs used are at their long run optimal levels.

The results obtained from such regressions can be compared to previous research, in particular, research that relates to the marginal value of crops. Yoder (2014) uses a model that assumes the quantity of water applied is maximized to measure the effects of water policy on different crops. He uses marginal revenue/(acre-ft per acre) to calculate the marginal value of each crop at different acreages. My model estimates the impact of several independent variables on average revenue which, as previously stated, is equal to marginal revenue in the long run. The results of such a model can be further expanded to determine marginal revenue and compare the results to other models, such as Yoder's (2014).

The dependent variable, average revenue, is used because it is predicted that the average farm revenue produced by irrigated crops is highly correlated with irrigation water quantities. Furthermore, due to long-run implications, it is assumed that marginal revenue can be derived from average revenue to find the incremental worth of irrigation water. The more acres irrigated and farmed, the less each given acre will be worth and thus average revenue as well as marginal revenue will diminish. Therefore, I will only assume that constant returns to scale apply as a local property.

To ensure the results of this model are unbiased and reliable, statistical tools that minimize error are performed. Because the data is panel data, this model is subject to many different econometrics issues including specification errors, functional form errors, heteroskedasticity, autocorrelation and multicollinearity. Specification errors and mistaken functional form are corrected by re-evaluating the model as well as re-evaluating variables and theory. Heteroskedasticity and multicollinearity bias standard errors widen the standard errors gap, which is problematic to this model. To test for heteroskedasticity, a Wald test is run. To correct for its presence, the Newey-West method of correction is performed. Determining if multicollinearity exists is harder but can be done through a variance inflation factor (VIF) test. No method will correct for multicollinearity; only the combining or dropping of variables or change of data and theory will fix this econometric issue. Such tests and corrections are performed to determine the best-fitting model given data collected.

Data Description

The data used in this model is panel data, collected by the U.S. Department of Agriculture (USDA) as well as the U.S. Geological Survey (USGS) in a series of four surveys spanning fifteen years and collected for every county in Washington State. The dependent and independent variables used in this model are ratios of given data over the total harvested acreage in each county. This allows for percentage values and standardized units to be calculated to effectively determine the relationship between variables.

For each given year and each county, data was collected on acres harvested, acres irrigated, net sales, quantity of irrigation water applied per acre and percentage of acres dedicated to both orchard and vegetable production. The data for net sales, acres harvested and acreage dedicated to orchard and vegetable production was collected from USDA National Agricultural Statistics Service surveys for the years 2012, 2007, 2002 and 1997. Because of the nature of data collection on irrigation-related variables, data pertaining to irrigation acreage and application quantities are offset from all other survey data by two years, measuring data in the years 2010, 2005, 2000 and 1995. Such data was collected by the USGS and due to this time-series offset, it poses as a shortcoming of the model. The models used assume that such offset data essentially equals values for the years collected by the USDA and thus all data will be referred to as collected for the primary years 2012, 2007, 2002 and 1997.

Since information on average revenue per county cannot be directly obtained, an alternative price-based proxy is used. Average revenue is computed by dividing net farm sales for each given Washington State county by total acreage harvested in corresponding counties. This is important to note because the dependent variable, average revenue, is highly dependent upon changes in, as well as variables that affect, net sales and acres harvested. Net sales include information on the market value of all agricultural products sold in a given county, measured in thousands of dollars. Economic theory indicates that revenue is generated through price and thus a ratio of sales to acres harvested is a viable price average revenue proxy.

Acres harvested, percentage of land dedicated to orchard production and percentage of land dedicated to vegetable production are all independent variables collected by the National Agricultural Statistics Service surveys for the years 2012, 2007, 2002 and 1997. Acres harvested is used as the denominator in many of the ratios used in the model and it is composed of statistics on total acreage harvested in each county for given years. Land dedicated to orchards is a measure of all irrigated land, in acres, dedicated to orchard production (Orch) whereas land dedicated to vegetables (Veggies) is a measure of irrigated acres per county dedicated to vegetable production.

Acres irrigated and the quantities of water applied per acre are both independent variables collected by the USGS for the years 2010, 2005, 2000 and 1995. The acres irrigated are a measure of the total number of irrigated acres used in agricultural production for a given county (Irr); this data is measured in thousand acres. Quantity of water applied is a summation of the total water applied per acre to irrigated crops in millions of gallons per day (WperA).

All of the above-stated variables, measured in percent units, are used in the calculation of ratios accounting for each regression variable in my models. The dependent variable average revenue is equal to net sales divided by total acres. Acreage dedicated to orchard production (Orch) and acreage dedicated to vegetable production (Veggies) are both calculated by dividing their given acreage by the total acreage irrigated in each county. The quantity of water applied per county divided by the acreage irrigated in that given county is used to measure the water applied per acre (WperA). To account for the total amount of land irrigated in each county (Irr), the total acres irrigated are divided by total acres harvested.
The appendix provides a detailed description of each variable as well as descriptive statistics.

Statistical Results

A regression is performed as a log-log base model as well as an alternative linear model to determine the relationship between average farm revenue and various independent variables. The appendix provides summary statistics of the multiple regressions as well as scatterplots and charts of the various regressions performed.

Several econometrics problems arose when performing regressions, each affecting the results of this analysis. Such problems included finding the best-fitting model through tests for multicollinearity and heteroskedasticity. Autocorrelation could not be tested for due to the structure of the data, only four years of panel data being present. Therefore, autocorrelation is assumed to not be present. Because of the nature of this data, the question was posed: "Do time-invariant characteristics affect this model?" To answer this question, I performed a Hausman test. The results indicate a P-value, significant at a 0.05 level, of 0.0064 for my base model and 0.01 for the alternative model. Thus, both models are fixed for biasness between omitted time-invariant characteristics through the use of fixed-effects models.

After determining that both models should be estimated using fixed effects and finding standard errors to be large, I tested for heteroskedasticity using the Wald test. Results show a P-value of 0.00 significant at a 0.05 level, indicating a correlation between the variance of tested independent variables and the error term. Therefore, heteroskedasticity is present. To correct for this, I performed the Newey-West method of correcting heteroskedasticity through the computation of robust standard errors. It is important to note that all values for the regression remain the same except for the standard errors of each given independent variable.

The last test I performed was a standard VIF test, on both models, to account for multicollinearity. I did such to determine if correlation exists among the independent variables being regressed. Tables 1 and 2 provide the results of this test.

Table 1. Base Model (Log-Log)

Variable	VIF	1/VIF
lnIrr	13.93	0.071781
lnOrch	6.71	0.149081
lnVeggies	4.8	0.208131
lnWperA	1.35	0.738882
Mean VIF	6.7	

Table 2. Alternative Model (Linear)

Variable	VIF	1/VIF
Irr	1.63	0.612448
Orch	1.37	0.732238
Veggies	1.23	0.811838
WperA	1.06	0.945962
Mean VIF	1.32	

The results of this test indicate that very little multicollinearity exists between independent variables in either model. The only independent variable shown to exhibit significant multicollinearity is the variable that represents the percentage of land irrigated in each county (Irr) in my base model. This variable is not removed from my model because it is used to examine the relationship between water quantities and average farm revenue in fulfillment of my first research objective. Also, because the quantity of water exhibits slight multicollinearity, at 13.93, the removal of this variable is not that significant but it is important to note that correlation exists between quantity demanded and the other independent variables.

The results of this VIF test, the Wald test, Newey-West test and the Hausman test all lead me to believe that the most applicable model for this data is a fixed-effect, panel data estimator with robust errors. I perform such corrections on both my base and alternative model; the results are shown in table 3.

Table 3. Model 1: Log-Log Base Model

Dependant Variable is lnAR			
Variable	Coef.	Robust Std. Err	P-Value
lnIrr	0.531602	0.1358043	0
lnOrch	0.136252	0.0535825	0.016
lnVeggies	0.116227	0.0546279	0.041
lnWperA	0.172861	0.0227762	0
R-sq:	Within	0.4329	
	Between	0	
	Overall	0.0006	
Rho:	0.938938		
# of Obs:	112		

The statistical implications of such results indicate both the overall significance of the logged base model and of all given independent variables. This model exhibits a high "Within" R-squared value at 0.4329 as well as a high rho value at 0.938938, indicating that this model is a good fit and that most of the variance is a result of differences across panels. All independent variables are significant at a 0.05 level, as indicated by P-values. As a result, the impact of each independent variable on the dependent variable is expressed, in percentage terms, by corresponding coefficients. It is important to note that such coefficients represent the elasticity of each variable. To test whether elasticities vary across values of variables, a linear alternative model is performed. Table 4 shows the results of such a model.

Table 4. Model 2: Linear Alternative Model

Dependant Variable is AR			
Variable	Coef.	Robust Std. Err	P-Value
Irr	10884.78	2305.205	0
Orch	24.33889	13.46698	0.079
Veggies	0.337037	0.5662756	0.556
WperA	0.015225	0.001818	0
R-sq:	Within	0.3381	
	Between	0.0109	
	Overall	0.0124	
Rho:	0.916599		
# of Obs:	120		

Resulting P-values indicate the significance of the percentage of irrigated land as well as water applied per acre at a 0.05 level and the significance of the percentage of acreage dedicated to orchard production at a 0.01 level. The remaining variable, percentage of acreage dedicated to vegetable production, is not statistically significant in the current estimated model. Most of the variance in the model is present due to variation between panels as indicated by rho at a level of 0.916599 Comparisons between this alternative model and the base model, as well as support through economic theory, indicate that the logged base model should be used in an analysis of average revenue.

Based on the statistical estimates of my base model, several conclusions can be drawn pertaining to my hypothesis regarding the effects of several independent variables on average revenue. The first conclusion is that the percent of irrigated land harvested in each county (Irr) model has the greatest economic impact on average revenue. This independent variable exhibits a positive relationship with the dependent variable, average revenue. Average revenue increases by 0.53% as the percent of irrigated land harvested in each country increases by 1%. The quantity of water is also statistically significant at a P-value of 0. The application rate of irrigation water per acre (WperA) is another very statistically significant variable, having a P-value of 0. The model indicates that an increase of 1% in irrigation rates per acre leads to a 0.17% increase in average revenue per county. The percentage of land dedicated to both orchard and vegetable production is also significant at a 0.05 level. The percentage of land dedicated to orchard production (Orch) has a 0.13% impact on average revenue and the percentage of land dedicated to vegetable production (Veggies) has a 0.11% impact on average revenue.

Several conclusions can be drawn from such results. Pertaining to my research objectives, it can be noted that the relationship between water quantities and average farm revenue is economically significant, having a large positive elasticity. Also in relation to my research objectives, it is important to note that the two high-water-using and profit-generating crop variables exhibit economically significant, positive relationships with average farm revenue. Both research objectives are fulfilled and the results hold true to my original hypotheses; each independent variable exhibits a positive relationship with the dependent variable, average revenue.

In comparison to prior literature, my empirical findings are similar in several ways to those of Yoder (2014) and Whittlesey (2003). My empirical results, like theirs, find that the acreage of high-valued crops (i.e., orchard crops) and alternative crops (i.e., vegetable crops) in each county are both highly correlated with average revenue as well as marginal revenue. As I expected, the empirical results of my alternative model yield a positive correlation between average revenue and quantity of water applied as well as irrigation application rates. Such results complement those of Yoder's who finds that the quantity of water applied per acre is highly correlated with both average revenue and thus marginal value of water per acre.

Conclusions

The subject of irrigation water is so vast and so many variables affect irrigation usage that it is hard to distinguish between, let alone find a relationship among variables. Despite this, I believe that my model can serve as a basis for understanding the basic relationship between average revenue and several independent variables including water applied per acre, crop types and total irrigation acreage.

This investigation fulfills my two research objectives: determining the relationship between average farm revenue and the quantity of irrigation water applied as well as the relationship between average farm revenue and crop types. As indicated by my model, average revenue per county exhibits a strong positive relationship with the amount of irrigation water applied in each county. Average revenue also exhibits a strong relationship with high-water-using, profit-generating crop types. Increased levels of irrigation as well as increased high-value crop production leads to higher average revenues per county. Higher levels of irrigation are correlated with higher-valued crop types and thus, greater revenue is generated. Furthermore, elasticities between levels of demand are believed to be constant, exhibiting diminishing returns to scale. This indicates that the rate of return on inputs to average revenue, such as water quantities, decreases as average revenue increases.

This research sheds light on the impacts of irrigation water on average revenue. The implications of this research indicate that irrigation water is a driver of average revenue and thus it is highly demanded. As farmers seek to maximize profit, the demand for irrigation water as well as high-valued crop types increases. Coupling this with the fact that both water and land are becoming scarce, a fine line must be drawn to prevent water over usage. Implications of this research shed light on production behavior, allowing policy makers to gain insight into why farmers use, and even waste, irrigation water. This research can also aid in the development of water allocation policies as well as crop forecasting.

This model possesses several shortcomings, the most important being the omission of input price and alternative variable input price (i.e., water and crop prices). To correct for omitted variable bias, data on water prices as well as crop prices should be included as independent variables. Based on economic reasoning, the modest addition of several variables including additional years, an index of crop prices and an index of irrigation prices, will result in an increase in the statistical significance of the model.
The results of an alternatively specified model should be closer in empirical findings to those of prior research.

The low overall R^2, as computed in the final model, indicates the possible misspecification of the dependent variable or variable omission. To correct for limitations of this specific model, current data must be analyzed and transformed. One particular misspecification may pertain to the form of the water quantity data. It is currently measured on a daily application basis instead of acre-ft-per-year as the rest of my data. I believe that this is distorting the correlation between average revenue and the independent variable (water per acre). To correct for this error, water per acre must be transformed to a per-year basis.

The model that I developed can further be expanded upon in multiple ways including an analysis of marginal value such as Yoder (2014) does in his IP research. Additions related to technology type can be used to measure the costs and benefits of irrigation efficiency as well as the marginal benefits of water application rates. I believe that further research into the relationship between average farm revenue and irrigation water will not only aid policy makers in gaining insight into farmer incentives, but will also shed some light on one of the world's greatest problems, water wastage.

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Appendix

Table A1: Data Description

abel	Variable Name	Data Period	Data Interval	Units	Ratio Calc
AR	Average Revenue	2012, 2007, 2002, 1997	annual	1000 $	Net Sales/Acres_H
rr	Percentage irrigated	2012, 2007, 2002, 1997	annual	acres	Acres_I/Acres_H
Orch	Orchard production percentage	2012, 2007, 2002, 1997	annual	acres	Orch. Acres/ Acres_I
Veggies	Veg. production percentage	2012, 2007, 2002, 1997	annual	acres	Veg. Acres/ Acres_I
WperA	Water applied Per Acre	2010, 2005, 2000, 1995	annual	1000 acre ft	Qw/ Acres_I

Table A2: Summary Statistics

Variable	Obs	Mean	Std. Dev	Min	Max
AR	154	6.949261	8.1051	0.5547	53.507
Irr	154	2.620291	15.222	0.2353	191.243
Orch	140	0.0006742	0.0004	0	0.0032
Veggies	127	0.0859597	0.1851	0	1.8779
WperA	156	0.1193007	0.2174	0	0.9361
lnAR	15	1.433	1.005	-0.58932	3.9798
lnIrr	153	-7.5071	0.72981	-9.6249	-5.7446
lnOrch	156	0.2438	0.6556	-1.4469	5.2535
lnVeggies	136	-3.6867	1.9799	-8.5172	-0.06603
lnWperA	119	-3.7094	2.0932	-9.7639	0.63015