DISSERTATION

WATER USE IN THE WESTERN U.S.: IRRIGATED AGRICULTURE, WATER LEASES, AND PUBLIC PREFERENCES

Submitted by

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WE HEREBY RECOMMEND THAT THE DISSERTATION PREPARED UNDER OUR SUPERVISION BY JENNIFER THORVALDSON ENTITLED WATER USE IN THE WESTERN U.S.: IRRIGATED AGRICULTURE, WATER LEASES, AND PUBLIC PREFERENCES BE ACCEPTED AS FULFILLING IN PART REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY.

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ABSTRACT OF DISSERTATION

WATER USE IN THE WESTERN U.S.: IRRIGATED AGRICULTURE, WATER LEASES, AND PUBLIC PREFERENCES

In the western U.S., water continues to be reallocated from agricultural to urban uses as a result of rapid population growth and urbanization. However, the negative implications of permanent rural-to-urban water transfers call into question the economic practicality and social acceptability of additional transfers. While some of the short-term economic impacts of permanent water transfers have been estimated, less attention has been given to the longer-term impacts of such transfers. There is also a need to evaluate the economic and social viability of emerging alternatives to permanent water transfers.

In addition to assessing the economic contribution of irrigated agriculture, this dissertation assesses the economic and social viability of water transfers and some of their alternatives, from the perspectives of both farmers and urban households. Chapter 1 provides a brief overview of western water law and motivation for the research. Chapter 2 assesses some of the longer-term effects of reduced irrigated acreage on the economic health of western rural counties. First, the relationship between irrigated agriculture and rural economic health is modeled via regression analysis of secondary data. The modeled relationship is then examined for structural breaks to test whether there is a minimum level of irrigated land necessary to sustain the economic health of rural agricultural communities. In Chapter 3, a

survey of households in the western U.S. uncovers public perceptions and preferences regarding water use, conservation, and reallocation; current levels of water knowledge; and willingness to pay a fee in support of various water conservation and reallocation programs. In Chapter 4, a survey of irrigators in eastern Colorado is used to estimate a supply curve for leased water and to identify some of the factors that influence farmers' decision to lease their water. Chapter 5 concludes and suggests areas for further study.

The research results will be useful to rural community leaders who are concerned with the evolution of their communities as their resources transition to urban use; urban planners as they consider water supply options; western households as they face the costs of water supply and reallocation programs; policymakers as they consider implementation of water lease markets; and farmers as they consider selling or leasing their water rights.

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CHAPTER 1: BACKGROUND, PROBLEM STATEMENT, AND STUDY PURPOSE

Western Water Law

In all western states, the allocation of water is governed at least in part by the doctrine of prior appropriation. Under this doctrine, the water itself is considered to be the property of the state, but individuals and groups can purchase the right to put the water to beneficial use[1] (Bureau of Land Management). The date when the water is appropriated toward a right determines the priority of that right, with earlier appropriations establishing more senior rights. The appropriations system, in contrast to the older riparian[2] system of the eastern states, treats the use of water as personal property separate from the land and allows water rights to be transferred or changed, subject to the protection of other water right holders (Howe and Goemans, 2003). Water right transfers or changes can be temporary or permanent and can involve changes in the purpose, timing, amount, and location of the diversion and/or use. A number of western states have a hybrid system of riparian and appropriative water rights[3].

Increasing Water Transfers

In the United States, population growth and changing values have increased demands on water supplies and watersheds, resulting in water use and management conflicts, particularly in the west, where populations are expected to increase 30 percent in the next 25

[1] Beneficial use is the use of a reasonable amount of water necessary to accomplish the purpose of the appropriation without waste, and includes irrigation, municipal, wildlife, recreation, mining, and household use.

[2] Riparian water rights are secured through land ownership. This water right, however, is only a usufructuary right and not a property right. The water may be used as it passes through the property of the land owner but cannot be unreasonably detained or diverted.

[3] These states include CA, KS, NE, ND, SD, OK, OR, TX, and WA (Bureau of Land Management).

years (Dobrowolski et al., 2008). In the west, increasing water demands have historically been satisfied through storage and conveyance projects, but the environmental and monetary costs of such large-scale infrastructural solutions have become prohibitive, and water in the west is fast approaching full appropriation[4] (Green and Hamilton, 2000). Non-traditional sources of water such as desalination and wastewater reuse are not likely to be a major component of new supplies (Easter et al., 1998), and although domestic water providers are interested in rationing future urban water demand with tiered pricing and conservation, these efforts are not likely to be sufficient to meet future demands (Colorado Water Conservation Board, 2004). Thus, there is increased interest in market-based reallocation among existing users.

Permanent sales of water rights from agricultural to municipal use have been the market mechanism of choice. Purchasing agricultural water rights provides municipalities with greater certainty and control of the supply and allows them to benefit from the appreciation of the water's value as an asset. Farmers also have incentive to sell—they receive more for their water than they could earn in agriculture (Brewer et al., 2007). However, water markets are more complex than markets for most other resources. Water has many public good characteristics and water rights are more akin to use rights rather than property rights (Howitt and Hansen, 2005). And because water rights often involve sequential users of the same water, water transfers that change the location, nature and/or timing of use can have adverse third-party effects (Brewer et al., 2007; Howitt and Hansen, 2005).

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[4] A river is considered to be fully appropriated if water diversions and withdrawals from the river sum to the total amount of water available.

Indeed, permanent water transfers have been shown to have adverse impacts on the rural communities from which the water is transferred, particularly if other sources of economic activity are not brought in to replace the economic activity lost as a result of the transfer (Howe and Goemans, 2003; Thorvaldson and Pritchett, 2006). Businesses that use agricultural commodities as inputs into their own production may be forced to purchase these commodities from farmers outside the region, resulting in faster leakage of money out of the regional economy. These non-local purchases may also entail higher costs, which may spur local businesses to relocate. Businesses that supply inputs to irrigated farms will experience reduced demand for their products, and local governments will experience reductions in property and sales tax revenues due to falling land values and reductions in retail trade associated with agriculture. Thus, if formerly irrigated land is not developed for another use—often the case when the community-of-origin is far-removed from the acquiring community—there is a real loss of economic activity in the community of origin. If the loss of irrigated land is followed by population out-migration in response to a bleak economic outlook, there will be further reductions in property and sales tax revenues. Left uncompensated, these costs could decimate the local economy. The experience of Crowley County, CO in the 1980s provides a stark example: 80,000 acre-feet (AF) of Arkansas River water were transferred to the cities of Denver and Aurora. Nearly 45,000 acres of cropland were fallowed and left undeveloped, which had devastating effects on the rest of the economy (Howe et al., 1990).

In addition, permanent water transfers require additional storage to firm[5] the yield for all parties and to provide for the replacement of delayed return flows from the fallowed

[5] Firm yield is the amount of water that can be counted on even in dry years. Roughly two AF of storage are required to produce one AF of firm annual yield for M&I use (CWCB, 2005).

lands (CWCB, 2005). This represents a loss of efficiency, as water is held in an unproductive capacity. Permanent transfers also tend to be costly, time-consuming, and legally complicated (Specter, 2006). And because these costs do not increase in proportion to the size of the transfer, there are economies of scale in the transfer of water (Howe and Goemans, 2003), which gives municipalities incentive to purchase large amounts of water and can result in regional "hot spots" where large areas of land are dried up and economic impacts are concentrated.

Problem Statement and Study Purpose

The potential negative distributional and efficiency effects of permanent water transfers call into question the desirability of additional transfers. In particular, the longer-term impacts of permanent water transfers need to be examined, and the viability of water-sharing alternatives needs to be assessed, as do public preferences for various water uses and water acquisition strategies. The three essays herein address these issues as follows:

1. Some of the short-term economic impacts of permanent water transfers have been estimated (Thorvaldson and Pritchett, 2006; Howe and Goemans, 2003). However, to better inform the allocation of water, it is important to estimate the longer-term impacts of reduced irrigated land on rural economies. Chapter 2 examines irrigated agriculture's role in the economic health of rural counties and tests for the existence of a threshold level of irrigated cropland in these counties.
2. Rural-to-urban water transfers have been taking place with very little public input. It is unknown whether households prefer to continue the current practice of water transfers or whether they prefer alternative strategies for addressing water scarcity.

It is unknown whether western households' are familiar with water supplies and institutions in the west, or whether such familiarity influences households' willingness to pay (WTP) for water initiatives aimed at addressing water scarcity. Chapter 3 presents the results of an Internet survey evaluating western households' water knowledge, water allocation and management preferences, and WTP for various water initiatives.

3. Temporary water leases from farmers have been proposed as a way to supply cities with water while avoiding some of the negative consequences of buy-and-dry permanent water transfers. However, few working water lease markets currently exist and the viability of additional lease markets needs to be evaluated. For instance, what factors play a role in farmers' decision to lease? How much water are farmers willing to lease and at what price? Chapter 4 discusses the results of a survey that asked these questions of irrigators in Colorado's South Platte Basin.

The results of this research will be useful for farmers, agricultural communities, urban water providers, and other water stakeholders. The results will be particularly useful to farmers as they contemplate possible offers to sell or lease their water rights; rural community leaders and policymakers as they contemplate policies and programs for rural economic growth; and urban planners as they contemplate various water supply strategies and potential compensation for rural communities. The results will also be useful for policymakers in general. When debates arise over the desirability of water conservation or reallocation, it is essential for policymakers to know which policies and programs are likely to garner the most financial and political support. And when devising agreements between rural and urban interests, the diverse interests of the public need to be considered.

CHAPTER 2: IRRIGATED ACREAGE THRESHOLDS

Problem Statement

As populations in the western U.S. continue to grow, further reallocations of water from rural agricultural use to municipal use are expected to occur (Colorado Water Conservation Board, 2004). While farmers are compensated for the sale of their water rights, the surrounding region can suffer economically if the proceeds from the sale are not reinvested in the local economy. Such reinvestment is unlikely because relatively few investment and spending options exist in most rural agricultural economies in the absence of development or urban encroachment. Additionally, a farmer who sells his or her water rights is more likely to move out of the region, which may spur the out-migration of other farmers who face increased input costs, other business-owners who experience reduced demand, and other residents who experience reduced incomes (Lopez et al., 1988). Indeed, one of the key threats of permanent water transfers is the loss of a critical mass within the farming community (Cortese, 1999). Some rural areas of the west have passed regulation to reduce the transferability of water rights due mainly to concerns about the long-term economic health of the area and fears that the loss of agricultural productivity will lead to increased levels of unemployment and other social issues (Hanak, 2005).

As pressure mounts to transfer water from agriculture to municipal uses, rural community leaders seek information about the level of irrigated agriculture to maintain in a region. Whether a loss of irrigated acres results in the mass out-migration of people and the closure of local businesses will depend on the size, strength, and diversity of the rural economy before the transfer and the number and magnitude of previous shocks the regional economy has experienced, including previous losses of irrigated land. For instance, counties that have very high levels of irrigated land may be able to dry up a portion of that land without causing severe economic damage. On the other end of the spectrum, counties that have very low levels of irrigated land may already have alternative industries in place and may not be highly dependent on irrigated agriculture for their economic base, and thus may be able to withstand further reductions in irrigated agriculture. Counties in the middle of these two extremes may be the most sensitive to a reduction in irrigated land—they may depend to a large extent on irrigated agriculture as an economic engine but not have so much of it that they can lose a large amount without experiencing adverse economic consequences.

Study Objectives

This research contributes to the limited but growing literature concerning the relationship between irrigated agriculture and the overall economic health of rural counties. A better understanding of irrigated agriculture's role in the rural economy is critical as rural communities are confronted with additional water transfers. State and local officials seek a better understanding of factors that contribute to economic health so they can better allocate resources. This knowledge can help guide policy decisions and rural economic development strategies. Furthermore, because of the economic interdependence between rural and urban regions, improved understanding of the factors that contribute to rural economic health is also of national importance due to the economic interdependence between rural and urban regions (Weber, 1995: Castle, 1995).

The objective of this study is to uncover the relationship between irrigated agriculture and economic indicators in rural western counties, with the ultimate goal of examining these relationships for evidence of a threshold level of irrigated land. The first question addressed by this study is whether a healthy irrigated agricultural sector is a necessary condition for a healthy rural economy. While some studies support the popular belief linking farming to healthy rural economies (e.g., MacCannell, 1998), others refute this premise (e.g., Deller et al., 2003). A unique contribution of the study is the examination of irrigated agriculture rather than the broader agricultural sector. Because irrigated agriculture generally has higher input and labor requirements and generates higher sales than dryland agriculture, it has greater potential for linkages to the rest of the economy and may thus play a more critical role in the continued viability of the regional economy. The second question addressed by this study is whether irrigated agriculture's economic contribution depends on the current level of irrigated agricultural activity. Stated alternatively, is the relationship between irrigated land and rural economic health constant, or is there a threshold level of irrigated agriculture below which the local economy does not have enough economic activity to sustain itself? The question of a threshold level of irrigated land is of concern to rural community leaders and businesses, and represents another unique contribution of the essay. The next section describes some of the ways in which the economic contribution of irrigated agriculture has been estimated and outlines the approach used here.

Measuring the Economic Contribution of Irrigated Agriculture

While the scale of the irrigated agriculture industry, as measured by gross sales or employment, gives an idea of its relative importance to an area, it only captures the direct contribution of the industry. By providing a representation of an industry's linkages with households, institutions, and other industries, input-output (I-O) models can be used to trace out the wider economic contribution of an industry. However, like any model, I-O models have a number of limitations. First, I-O models are based on the assumption of perfectly elastic supply, which implies that changes in output do not cause any changes in real prices (Hughes, 2003). Downstream industries that purchase the agricultural output for further processing (e.g., food processing, livestock production) may experience increased costs if they have to shift to non-local suppliers as a result of the reduction in local crop production—changes that would not be captured in an I-O model. Second, by failing to account for adaptations that farmers and rural economies will undergo in response to such reductions, I-O models may overstate the economic losses of large-scale reductions in irrigated land (Pritchett et al., 2003), rendering I-O models appropriate only for relatively small impacts that would not change the underlying structure of the economy. Finally, the ultimate outcome of a reduction in irrigated acres may depend on the amount of irrigated land in the region before the reduction took place, making it useful to test for changes in the relationship between irrigated land and regional economic health depending on the initial amount of irrigated land. Because I-O models are linear and static, they do not easily allow for such considerations.

Computable general equilibrium (CGE) models are similar to I-O models but are more flexible by allowing prices to change and allowing for factor substitution and non-linear production functions. However, increased flexibility comes at the cost of increasing the number of implicit assumptions made when building a CGE model. For instance, because CGE models always contain more variables than equations, the researcher must choose which variables to set outside the model—a choice which can impose causality and define the results

(Mitra-Kahn, 2008). So-called "dynamic" CGE models use the endogenous variables as exogenous variables in another model and back again. As such, the dynamics are actually static solutions recalculated repeatedly; thus, the original benchmark values and parameters tend to persist in any modeled future (Mitra-Kahn, 2008).

This study uses econometric techniques to assess the relationship between irrigated land and economic health. Controlling for other factors that are expected to affect economic health allows the effect of irrigated land to be isolated, while including more than one time period captures some of the adaptations that may take place as the amount of irrigated land changes. The approach allows the constant returns-to-scale assumption of I-O models to be relaxed and can inform the closure rules used by CGE modelers. Especially important for the present study, regression analysis can be used to test for and incorporate structural breaks in the relationship to address the question of a threshold level of irrigated land. A number of methods for doing so are described in the next section.

This section has outlined the rationale for using econometric analysis to assess the economic contribution of irrigated agriculture. One of the primary purposes of this study is to examine the question of a non-constant relationship between irrigated agriculture and rural economic health. Before building an empirical model to test for such a threshold, it is necessary to establish a theoretical model of economic health.

Theoretical Considerations

Growth Theory

The Solow model is the starting point for most analyses of growth (Romer, 2006). The Solow model focuses on four variables: output (Y), capital (K), labor (L), and technology

(A). Assuming a Cobb-Douglas production function and labor-augmenting technology, output in period *t* is:

$$Y(t) = K(t)^{\alpha}[A(t)L(t)]^{1-\alpha}. \quad (1)$$

The principle conclusion of the Solow model is that the accumulation of physical capital cannot account for the vast growth in output per person over time nor the vast geographic differences in output per person. And since technology is non-rival, differences in technology are unlikely to be important to cross-country income differences (Romer, 2006). This is even more likely to be the case when the analysis is done at the county level, which is the case presently, due to counties' geographic proximity and relatively porous borders.

Extending the Solow model to include human capital (H), output at time *t* becomes (Romer, 2006):

$$Y(t) = K(t)^{\alpha}[A(t)H(t)]^{1-\alpha} \quad (2)$$

where H includes both raw labor (naturally endowed skills) and human capital (acquired skills). Another type of capital not explicitly included in the original Solow model is natural capital—things like natural resources, environmental quality, etc. The type of natural capital of primary concern presently is irrigated land, which can easily be incorporated into the production function, which is now represented as:

$$Y(t) = K(t)^{\alpha}R(t)^{\beta}[A(t)H(t)]^{1-\alpha-\beta} \quad (3)$$

where R denotes irrigated land. Social infrastructure is another potential source of income differences in per capita output across countries. Romer (2006) lists three categories of social infrastructure: the government's fiscal policy (e.g., taxes); factors that influence the private decision-making environment (e.g., crime level).

The conclusions of the Solow model rely on two major assumptions: perfect competition among firms and constant returns to scale. The new economic geography, led by Krugman (1991), developed mathematical models of regional growth that allow these two assumptions to be relaxed by emphasizing the roles of agglomeration (e.g., market size and density) and dispersal (e.g., market distance and transportation costs) in economic growth.

Measures of Economic Health

Any number of measures could be used to assess the economic health of a region, none of which entirely captures the concept or should be considered as the sole "correct" measure. Rural communities vary in the opportunities and challenges they face and the economic development goals they set, so that considering only one measure of economic health would yield unnecessarily specific results and would limit their usefulness. Considering several indicators of economic health can reveal patterns and strengthen conclusions. Furthermore, while most indicators of economic health reinforce one another, this is not always the case. For instance, population growth in an area may result in a higher unemployment rate. These factors led to the consideration of four indicators of economic health: population density, value of sales per capita, industrial diversity, and unemployment rate. Each of these is discussed next.

While a county's population is not a measure of its economic health *per se*, population loss plagues many communities in rural America today (Federal Reserve Bank of Chicago, 2006) and a number of researchers have used population as a measure of economic health in rural America (e.g., Wagner and Deller, 1993 and DeWitt et al., 1998). It is expressed here as a density to control for the effect that county size has on population.

Value of sales—or output—is the measure of economic health used in the Solow model. While median income—a common economic indicator—provides some insight into the economic health of a region's residents, it is not always a good indicator of the overall economic health of a region. Higher household incomes may not benefit a county if the income leaks to neighboring counties due to a lack of spending opportunities locally (Chestnutt et al., 2009). More importantly, one of the main concerns surrounding the continued dry-up of irrigated cropland—and indeed the research hypothesis here—is that other businesses in the region will also "dry up" as a result, further reducing sales in the region. Including this variable will test this hypothesis and tell us whether these concerns are well founded. This variable is expresses on a *per capita* basis to control for the effects that county size has on value of sales.

Industrial diversity is commonly pursued as a regional economic development strategy to achieve the goals of economic stability and growth (Wagner, 2000). Industrial diversity is particularly relevant for rural communities facing rising pressure to sell water rights to municipalities; as observed by Howe and Goemans (2003), a more diverse economy can better absorb the adverse impacts of water transfers due to alternative employment and investment opportunities.

Unemployment rates in rural labor markets have been a concern since the recession of the early 1980s. A high unemployment rate[6] indicates a general lack of job opportunities, which may discourage new residents from locating to the region and may encourage the out-migration of current residents in search of job opportunities elsewhere. Even if they remain in

[6] The Congressional Budget Office considers 5.2 percent unemployment to be the standard for full employment (Gongloff, 2003).

the region, unemployed residents have less income to spend on goods and services in the region. Unemployment is one of the indicators of economic health used by the Federal Reserve. It is measured as the ratio of unemployed persons to the civilian labor force, which is made up of all persons in the civilian non-institutional population (Bureau of Labor Statistics).

This section has shown that, while economic health is an indefinite concept, it can be proxied by output, population, and employment. The case has also been made for including industrial diversity as an additional measure of economic health. The next section discusses the study area under analysis, the set of variables included in the analysis, and the model specifications used to perform the analysis.

Methodology and Data

Study Area

Rural counties in the U.S. vary widely in their socioeconomic characteristics, climates, and natural resource endowments, such that a model of economic health that included all rural counties in the U.S. would be unrealistic (Watson and Thilmany, 2008) and would yield fewer useful results than a model that focuses on a specific region. Furthermore, the goal of this study is to provide useful i nformation to those rural counties that are facing i ncreasing pressure to transfer water to urban areas—a pressure that is particularly strong in the Inter-Mountain West, where rapid population growth and urbanization are placing great pressure on the region's scarce water supplies. While rural counties in other parts of the nation are also experiencing growth and urbanization pressures, these counties have relatively abundant water supplies, many of which are administered under a different system of water laws, such that their inclusion would yield less conclusive results and fewer useful insights.

The analysis was thus limited to rural counties with positive amounts of irrigated land in thirteen western states.[7] This allows for isolation of the irrigated agricultural sector while including enough variation to be detected by statistical analysis and to allow a number of general conclusions to be drawn. While it is recognized that the term "rural" can have several meanings and definitions, it was necessary to use some type of classification. Thus, rural designations were based on having a USDA-ERS urban-rural continuum code of six or higher (Table 1). There are 568 such counties in the study area.

Table 1: Urban-Rural Continuum Codes (USDA-ERS, 2003)

Urban-Rural Code	County Characteristics
1	Counties in metro areas of 1 million population or more
2	Counties in metro areas of 250,000 to 1 million population
3	Counties in metro areas of fewer than 250,000 population
4	Urban population of 20,000 or more, adjacent to a metro area
5	Urban population of 20,000 or more, not adjacent to a metro area
6	Urban population of 2,500 to 19,999, adjacent to a metro area
7	Urban population of 2,500 to 19,999, not adjacent to a metro area
8	Completely rural or less than 2,500 urban population, adjacent to a metro area
9	Completely rural or less than 2,500 urban population, not adjacent to a metro area

Panel Data

Panel data contain two kinds of information: cross-sectional information, reflected in the differences *between* counties, and time-series information, reflected in the changes *within* a county over time. Panel data regression techniques allow a researcher to take advantage of both of these types of information by including multiple counties and two time periods. This reduces collinearity, allows for more efficient estimation, and allows for better analysis of dynamic adjustment—by exploiting information on the dynamic reactions of each of several counties, the need for a lengthy time-series can be avoided (Kennedy, 2003).

[7] The states included in the study are AZ, CO, ID, KS, MT, NE, NV, ND, OK, SD, TX, UT, and WY.

Data were collected for two periods, creating a panel of 1,136 observations. Not all datasets were available on an annual basis; thus, the years representing the "early period" and "late period" differed across some of the variables. For example, due to the timing of the Census of Agriculture, irrigated land values are available for 1997 and 2002, whereas data on the number of healthcare establishments were reported for 1998 and 2003. While the exact years differ across some of the variables, the lagged year for each variable is earlier than the non-lagged year of all other variables. In any case, any problems that might arise as a result of these differences are mitigated by including a large study area and a larger lag (typically five years) between the two time periods. This approach is similar to that used by Deller et al. (2003), who used a five-year time period in their study of per capita income. The dependent and explanatory variables are discussed next and are listed in Tables 2 and 3.

Dependent Variable: Rural Economic Health

The dependent variable of interest is economic health. Four indicators of economic health are examined in separate regression equations: population density, value of sales per capita, industrial diversity, and unemployment rate (Table 2).

Table 2: Dependent Variables and Years of Data

Dependent Variables	**Years of Data**
Population	1998 and 2003
Value of Sales	2001 and 2006
S-W Index	2002 and 2004
Unemployment	1998 and 2006

There are several ways of measuring industrial diversity, two of which are discussed here. The national average (NA) measure assesses the deviation of the regional distribution of economic activity from the national distribution. It has been hypothesized that the more similar a region's industrial composition is to that of the nation, the more stable it should be relative to other regions. However, because the national distribution changes over time, the NA measure does not determine whether the distribution of economic activity within a region itself has become more or less diverse over time (Conkling, 1963), only whether it has become more or less diverse relative to the nation.

The entropy method uses a uniform distribution of economic activities, rather than the national average, as a comparative norm, and can be calculated as:

$$D(E_1, E_2, \ldots E_n) = -\sum_n E_i \log_2 E_i \tag{4}$$

where n represents the number of industries and E represents the proportion of total regional employment that is located in the ith industry. A value of zero indicates minimum entropy (or complete specialization), and occurs when the economic activity of a region is concentrated in only one industry, as indicated by one E_i that equals one and the remaining E_i equaling zero. A value of one indicates maximum entropy (or perfect diversity), and occurs when all industries are present in the region and $E_1 = E_2 = E_3 = 1/n$ (Attaran, 1986).

As noted by Wagner and Deller (1998), while entropy measures account for the *number* of industries, they fail to capture the linkages between those industries. For example, if employment is shared across a variety of industries, but these industries are all closely tied to just one struggling industry, then the economy is not truly as diverse as these measures would indicate. Nonetheless, in order to analyze specific functional relationships, some measure of diversity is required. The entropy measure offers an index which can be utilized for a ranking of regional economic diversities and thus provides a reference point for further analysis of causal relationships in regional economic performance (Hackbart and Anderson, 1978). Kort

(1981) compared four measures of industrial diversity according to their ability to explain regional economic instability in 106 metropolitan areas, finding the entropy measure to be the most satisfactory measure. The present study uses an entropy measure known as the S-W index (Shannon and Weaver, 1949) as the chosen measure of industrial diversity.

Explanatory Variables

The Solow model and its extensions have outlined four broad categories of factors necessary for economic growth: physical capital, human capital, natural capital, and social infrastructure. The focus of this study is the role that irrigated agriculture plays in regional economic health; thus, the explanatory variable of primary interest is irrigated land, as defined and measured by the National Agriculture Statistical Service (NASS)[8]. Because it requires numerous and varied inputs and imparts higher land values compared to dryland agriculture (Torell et al., 1990; Smith et al., 1996), irrigated land is expected to contribute positively to the economic health of a county.

In order to isolate the effect of irrigated agriculture, it is necessary to control for the effects of other factors that may also influence regional economic health. While there is some evidence that the economic success of rural communities is related less to traditional variables like the presence of an interstate highway or adjacency to a metropolitan area than to variables like local leadership, ability to mobilize resources, attitudes of the population, and cooperation among local and outside organizations (DeWitt et al., 1988), such variables are difficult to quantify reliably and do not allow for direct comparisons across studies. Thus, this study relies

[8] As defined NASS, *Irrigated Land* includes all land watered by any artificial or controlled means. This includes supplemental, partial, and pre-plant irrigation. Each acre is counted only once, regardless of the number of times it was irrigated or harvested. Livestock lagoon waste water distributed by sprinkler or flood systems is also included.

largely on traditional variables. Table 3 lists the explanatory variables, the years of the data, and the expected sign[9] of each variable's relationship to economic health. The table is followed by a description of each variable and the rationale for its inclusion. The data sources are listed in Appendix A.

Table 3: Explanatory Variables, Years of Data, and Expected Sign

Explanatory Variables	**Years of Data**	**Expected Sign**
Physical Capital		
Highway Spending per Acre	1997 and 2002	Positive
Non-farm Establishments	1997 and 2005	Positive
Human Capital		
Lagged Population	1997 and 2002	Positive
Lagged Unemployment	1990 and 1998	Negative
% Healthcare Establishments	1998 and 2003	Positive
% of Workforce Female	1990 and 2000	Positive
% of Population Caucasian	2000 and 2002	Positive
% of Population over 60	1990 and 2000	Negative
% of Population with Bachelor's Degree or Higher	1990 and 2000	Positive
% of Households headed by a Married Couple	1990 and 2000	Positive
Social Infrastructure		
Median Income	1989 and 1999	Positive
Violent Crimes	1997 and 2002	Negative
USDA ERS Urban-Rural Continuum Code	1993 and 2003	Negative
Tax Revenue per Capita	1997 and 2002	Positive
S-W Index	1993 and 2002	Positive
Natural Capital		
Irrigated Land	1997 and 2002	Positive
Drought	1997 and 2002	Negative
Average Farm Size	1997 and 2002	Negative
USDA-ERS Natural Amenity Rank	1993 and 2003	Positive
USDA Farm Production Region	N/A	Various

Highway Spending per Acre: Transportation costs are important to businesses because they affect the cost of acquiring inputs and shipping products to their final markets. These costs are likely to be lower for a firm that locates in a county with a well-developed system of highways. This variable is expressed as dollars per acre of land area, and is an indicator of the

[9] These are the expected signs when the dependent variable is *Population Density*, *Sales per Capita*, or *Industrial Diversity*. The opposite sign is expected when the dependent variable is *Unemployment Rate*.

quality and/or extent of transportation infrastructure in a county, which in turn is an indicator of firms' access to suppliers and customers.

Non-farm Establishments per Acre: It has been established that, *in the absence of other development,* a loss of irrigated land will adversely affect the regional economy (Howe et al., 1990). The number of non-farm establishments[10] serves here to account for the presence of other sources of economic activity that could potentially replace that lost from irrigated agriculture. This variable encompasses all other non-agricultural industries, which is sufficient for the present analysis—the goal of this study is to isolate the effect of irrigated agriculture, so it is not necessary to analyze any other industry in particular.

Lagged Population: Because a county's current population will affect its future population, this variable is included in the *Population* equation.

Lagged Unemployment: In addition to serving as an indicator of economic health itself, the unemployment rate is also likely to directly affect the value of sales per capita, and is thus included as an explanatory variable in that regression.

Proportion of Healthcare Establishments: The availability of low-cost quality healthcare is expected to attract businesses and workers. Unfortunately, good measures of healthcare costs and quality are difficult to obtain and have yielded mixed results (Drabenstott and Smith, 1995). Nonetheless, this variable serves as a rough proxy for worker health. Healthcare establishments are those that provide healthcare and social assistance.

Percentage of Female Workers: Malizia and Ke (1993) found the proportion of female workers to have a negative effect on unemployment in metropolitan areas. The authors theorize that

[10] As defined by the U.S. Census Bureau, an establishment is a single physical location at which business is conducted, or where services or industrial operations are performed.

areas with more female workers may experience lower unemployment rates because they offer more stable "pink collar" jobs. This variable is included to control for any such effects.

Percent Caucasian: Malizia and Ke (1993) found the proportion of nonwhites to have a positive effect on unemployment in metropolitan areas. The authors theorize that areas with fewer nonwhites may experience lower unemployment rates because they offer jobs that require more education and training, which are less prone to layoffs. Nonwhites may experience more layoffs due to skill level, discrimination, or both. This variable is included to control for any such effects in rural counties.

Percent over 60: The older population grew rapidly in many rural places in the 1990s and this trend is likely to continue as baby boomers retire. Retired persons tend to increase property and sales tax revenue without straining social services such as school systems or criminal justice systems (Chestnutt et al., 1993), and thus may stimulate economic activity in a region. However, a disproportionate age distribution, with either heavy dependency on younger or older populations, has been found to have a dampening effect on income growth (Deller et al., 2003). This variable aims to control for these effects.

Percent Bachelor's Degree: The educational characteristics of an area generally reflect the quality of its workforce (Whitener and Parker, 2007). However, the relationship between educational levels and rural economic growth has been found to be weak at best, leading to what is known in the literature as the human capital puzzle (Benhabib and Spiegel, 1994; Bils and Klenow, 2000; Pritchett, 2001). Whitener and Parker (2007) found that per capita income and employment increase when the number of adults with some college education increases. Meanwhile, Deller et al. (2003) found higher education to have a mixed and somewhat weak influence on rural income growth. DeWitt et al. (1988) and Killian and Parker (1991) were unable to find a significant effect of educational levels on rural employment growth. This variable indicates the percentage of a county's population with at least a Bachelor's Degree. While a formal college education is not the only way to acquire knowledge and skills, other forms of skill acquisition are difficult to measure. Nonetheless, traditional educational indicators such as this still contain useful information regarding the relative level of education across counties and are sufficient for the purposes of this study and have been used by other researchers (e.g., Deller et al., 2003; Pede et al., 2008).

Percent Married: Married couples may have different spending patterns, may be more likely to have children, and may differ from their single counterparts in other ways that affect a county's economy. The percentage of households headed by a married couple is included to control for any such effects.

Median Income: Low wages may encourage firms to expand or move to a county, thus increasing employment levels (Drabenstott and Smith, 1995), while high wages may encourage population in-migration (Smith, 1975). Summers (1986) proposed that workers queue for high-wage jobs, suggesting a positive relationship between wages and unemployment. On the other hand, higher wages may reduce unemployment if high-wage industries have larger multiplier effects, spurring labor demand in other industries (Evans and McCormick, 1994). This variable is included as an explanatory variable in the *Unemployment* equation to control for the effects that wages have on labor supply and demand.

Violent Crimes: This variable indicates the number of violent crimes known to police in a given year, and is expected to dampen economic growth.

Ruralness: While many rural counties are characterized by sparsely-populated small towns with open countryside in between, others contain relatively large urban areas which may contribute significantly to economic activity in the county. The ERS urban-rural continuum (Table 1) codes categorize counties by degree of urbanization and serves here as a discrete variable. Transportation costs are likely to be lower for a firm that locates in a county closer to its final markets. In fact, a rural county's proximity to metropolitan areas may play as large a role as the market situation of its primary commodity (Weber, 1995; Whitener and Parker (2007). Because higher urban-rural codes indicate greater ruralness, this variable is expected to be negatively correlated with economic health. Because the ERS urban-rural continuum code is partially defined by population, this variable is replaced by urban adjacency in the *Population* equation.

Tax Revenues per Capita: Taxes are a business cost, with low tax rates thought to encourage business location and boost employment and income (Drabenstott and Smith, 1995). This variable serves as an indicator of business costs and government services.

S-W Index: In addition to serving as an indicator of economic health, industrial diversity is thought to enhance economic performance by 1) shielding a region from the adverse effects of economic shocks and 2) increasing the proportion of intermediate and final demand that can be supplied locally, thereby slowing the leakage of money out of the local economy. While industrial specialization takes advantage of economies of scale (Skyes, 1950) and competitive advantage (Diamond and Simon, 1990), the performance of an area dominated by one sector is likely to be closely tied to the performance of that sector, which can become a liability for the area if the core industry suffers a national or regional downturn (Fitchen, 1995). In order for an economy to withstand supply and demand shocks, it must either maintain its competitive advantage or have enough variety of industries to reemploy displaced workers (Malizia and Ke, 1993).

Furthermore, an economy's size and diversity influences its ability to generate agglomeration externalities, which are generated via three mechanisms:

1. Input-output linkages: Input-output linkages have two main roles in driving agglomeration. The first is a supply access effect, whereby firms benefit from being close to a large supply of intermediate input producers, which reduces transport costs and attracts more firms. The second is a market access effect, whereby firms experience increased demand and higher profits due to the proximity to the markets for their output (Mulligan et al., 1985).
2. Matching: This theory argues that denser agglomerations improve the quality of matches among firms and workers (Carlino et al., 2007).
3. Knowledge spillovers: This theory argues that the geographic concentration of people and jobs facilitates the spread of information among workers and firms.

However, studies of the relationship between industrial diversity and growth have yielded contradictory results. For instance, while Attaran (1986), Neumann and Topel (1991), and Malizia and Ke (1993) all found industrial diversity to be associated with lower unemployment, Attaran (1986) found an unexpectedly negative correlation between industrial diversity and per capita income. Among the explanations for this empirical inconsistency are small sample sizes, poor measures of diversity and economic growth, and overly simplistic statistical methods (Kort, 1981; Malizia and Ke, 1993; Siegel et al., 1995). Units of analysis have mostly been states and metropolitan areas (Dissart, 2003). A contribution of this study is to examine these relationships at the rural county level and with a large sample size by including the S-W index as an explanatory variable in the *Value of Sales, Population*, and *Unemployment* equations.

Drought: Precipitation patterns will likely influence the economic contribution of irrigated agriculture. Drought data are not available at the county level. Nevertheless, the Palmer Hydrological Drought Index (PHDI[11]) is included to partially control for this effect.

Average Farm Size: Goldschmidt (1947) argued that the structure of agriculture—given by the number and size of farms—in a local area affects the economic vitality of towns near those farms. Using data from Idaho, Marousek (1979) showed that smaller, subsistence-type farms have a higher marginal propensity to purchase farm inputs and consumer goods locally, thus creating a larger multiplier effect and reducing the out-migration of businesses out of the local community. In contrast, Goetz and Debertin (1996) found that population loss was smaller in counties with a higher proportion of farms in the highest sales category (those selling $250,000 or more annually). This variable is included to control for the potential effects of farm size.

Natural Amenity: An area's natural amenities can enhance farmland values (Henderson and Moore, 2005). Natural amenities can also influence the demand for land uses. Some characteristics that make locations more desirable to agricultural producers—such as climate—may also make those locations more desirable to households and other industrial sectors (Cragg and Kahn, 1999; Shumway and Otterstrom, 2001; Hunter et al., 2005). The topography of an area may limit the amount of land suitable for growing crops or erecting buildings, while the presence of mineral deposits may result in local specialization in extractive industries (Conkling, 1963). The USDA-ERS natural amenity rank is a measure of the physical characteristics of a county that enhance it as a place to live. It is constructed by combining six measures that reflect the environmental qualities that most people prefer: warm

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[11] The PHDI is a monthly value that indicates the severity of a wet or dry spell. The index generally ranges from -6 to +6, with negative values denoting dry spells, and positive values denoting wet spells.

winter, winter sun, temperate summer, low summer humidity, topographic variation, and water area. The ranking is based on deviations from the national mean, and ranges from one to seven. It serves as a discrete variable in the analysis.

Farm Production Region: The study area is comprised of counties in the Northern Plains, Southern Plains, and Mountain farm production regions. These regions differ in soils, slope of land, climate, distance to market, and storage and marketing facilities, all of which influence the types and yields of crops that can be grown there. A dummy variable based on farm production is included to control for these differences, with the Mountain region serving as the omitted dummy such that the estimated coefficients on the two remaining regional dummies are relative to the Mountain region.

Figure 1: U.S. Farm Production Regions (USDA, 1998)

Model Specification

Two estimation techniques were used, one of which focuses on the differences across counties and the other of which focuses on the differences in a county over time. Each technique has particular strengths and weaknesses, so that a comparison of results across techniques will allow for the detection of inconsistencies and will strengthen conclusions drawn from those results that are consistent.

Lagged Regressor Estimation

While the static nature of I-O models can be seen as a limitation, it can also be seen as an asset in the sense that the direction of causality can be known with certainty. This is not always the case with regression analysis using secondary data because it is impossible to control for all factors that influence the dependent variable or completely isolate one direction of a bi-directional relationship. Nonetheless, the direction of the relationship can be informed by economic theory and by examining the timing of changes to each of the variables. One way to achieve this is to put lagged variables on the right-hand side of the equation:

$$y_{it} = \alpha_i + \beta \boldsymbol{x}_{i,t-1} + \varepsilon_{i,t-1} \quad (5)$$

where y is to the particular measure of economic health under consideration; a is the intercept term; $\boldsymbol{x}$ is the vector of explanatory variables described in the previous section; β is the vector of parameters to be estimated; and ε is the error term. The reasoning is that if the value of an explanatory variable changed *before* there was a change in economic health, then the change in economic health is less likely to have caused the change in that explanatory variable: In this way, even if an explanatory variable is not truly exogenous, they can be considered *predetermined*. This method thus represents an improvement over pooled OLS in terms of endogeneity.

However, this method does not control for unobserved characteristics that affect a county in every time period. These unobserved characteristics may be correlated with a specific feature of some counties, in which case they are termed "fixed effects", or they may be randomly distributed across counties, in which case they are termed "random effects". If the influence of these unobserved characteristics is correlated with the included explanatory variables, OLS will yield biased results (Kennedy, 2003). While the use of panel data can alleviate the problem (Islam, 1995; Lee et al., 1997; Evans, 1998), this approach is somewhat limited here by the small number of time periods. The fixed effects (FE) and random effects (RE) estimators represent two alternative estimation techniques designed to address the problem. Each is discussed briefly next.

One way to improve estimation in the face of unobserved county characteristics is to include a dummy variable for each county, thus allowing each county to have its own intercept. The FE model involves a simple transformation of the data to allow these individual intercepts to be implicitly included without having a cumbersome number of dummy variables. This transformation consists of subtracting from each county's individual observations the average of the two observations for that county. Suppose the observation for the *i*th county in the *t*th time period is written as:

$$y_{it} = a_i + \beta \mathbf{x}_{it} + \varepsilon_{it} \qquad (6)$$

Averaging the observations for the *i*th county over the *T* time periods yields:

$$\overline{y_i} = a_i + \beta \overline{\mathbf{x}_i} + \overline{\varepsilon_i} \qquad (7)$$

The FE transformation involves subtracting Equation 17 from Equation 16:

$$y_{it} - \overline{y_i} = \beta(\mathbf{x}_{it} - \overline{\mathbf{x}_i}) + \varepsilon_{it} - \overline{\varepsilon_i} \qquad (8)$$

Running OLS on the transformed data yields the FE estimator, which is basically an instrumental variable estimator with the deviations from individual means as the instruments (Kennedy, 2003). FE estimation is the main technique used to analyze panel data and is one of the techniques used here. However, two main drawbacks of FE should be noted. First, the implicit inclusion of a dummy variable for each county results in a loss of $(N - 1)$ degrees of freedom (one degree of freedom is recovered by dropping the constant term). Thus, it works best when there are relatively fewer counties and more time periods. Second, the transformation causes all time-invariant variables to drop out, so that the marginal effect of these variables cannot be estimated, although this is only a problem if such variables are of particular interest, which is not the case presently. However, the elimination of cross-sectional variance in the independent variables increases standard errors.

The RE estimator is designed to overcome these two drawbacks of the FE estimator. By collapsing all observations for a county down to a single average over all time periods, the RE estimator ignores temporal variance and focusing solely on cross-sectional comparisons. The RE model assumes that the different intercepts are drawn randomly from a pool of possible intercepts. In this way, the intercepts can be treated as though they are a part of the error term. As a result, there is one common intercept for all counties and a composite error term for each county made up of two parts: the traditional random error plus the random intercept term for that county (Kennedy, 2003). While RE is more efficient than FE and allows the effects of time-invariant variables to be estimated, RE—like pooled regression—risks omitted variable bias if there is correlation between x and the composite error term (Greene, 2003). Furthermore, the RE estimator is most appropriate in experimental settings where the sample can be reasonably assumed to be random, which is not the case presently.

In summary then, the lagged and FE estimators are used here. This is similar to the approach taken by Neumann and Topel (1991) in their examination of state unemployment. In some cases, the authors restricted the intercept to be equal across all states in order to focus on the cross-sectional impact of the explanatory variables, while in other cases the intercept was allowed to vary across states in order to examine the within-state effects of the variables.

Functional Form

Theory gives little insight into the appropriate functional form for the growth equations, though much of the relevant literature assumes linear or logarithmic procedures (Wagner and Deller, 1998). Partridge and Rickman (1997) and Neumann and Topel (1991) estimated a linear *Unemployment* equation. In order to address the question of structural breaks, all variables here enter into the equations linearly. Logarithmic and quadratic forms of the irrigated land variable are then incorporated as a means of testing and allowing for a non-linear relationship, as discussed previously.

A Word on Spatial Dependence

A county is not independent of its neighbors, giving rise to the possibility of spatially-correlated error terms. Consider the following panel regression model (Song and Lee, 2008):

$$y_{it} = \mathbf{x}_{it}'\beta + \varepsilon_{kt} \tag{9}$$

In this case, the disturbances have random region effects as well as spatially autocorrelated residual disturbances:

$$\varepsilon_{kt} = v_i + \mu_{it} \tag{10}$$

In their model of technological dependence across countries, Ertur and Koch (2007) present an augmented Solow model that includes spatial externalities in both physical and human capital, purporting that technical progress depends on the stock of physical and human capital in other countries. The intensity of this spillover effect is assumed to be related to socioeconomic proximity, which they proxy with geographical proximity. Pede et al. (2008) use a spatial weight matrix based on income distance rather than geographical distance in their study of all U.S. counties.

However, technology disparities across counties are likely to be much smaller than those across countries, primarily because the boundaries between counties are much more porous, but also because counties are subject to the same federal laws and are beneficiaries of the same federal services. Furthermore, because the present study considers counties in the western U.S. only, their geographical distances are small relative to those between countries or between counties on different sides of the U.S. Further still, the present study considers rural counties only, such that their income distances are also small relative to a scenario in which all counties are considered. Partridge and Rickman (1997) found little evidence of spatial correlation of the error terms in their models of state unemployment, and Song and Lee (2008) show that the OLS estimator of the disturbance variance in a panel regression model with a spatially-correlated error component is asymptotically unbiased and weakly consistent without any restrictions on the regressor matrix. In any case, the present analysis addresses the possibility of spatial dependence by the inclusion of 1) the ERS urban-rural code, which provides information on a county's neighbors, and 2) regional dummies, which control for factors that may affect a group of counties simultaneously.

Testing for Structural Stability of Regression Models

The primary purpose of this study is to look for evidence of a structural break in the relationship between irrigated agriculture and rural economic health, with the ultimate goal of determining whether there exists a threshold level of irrigated land, below which too much economic activity has been lost and too many economic linkages broken that the local economy can no longer sustain itself. A number of methods for testing and modeling such threshold effects are used here, each of which is discussed next. Consider a linear model of unemployment in a county at a particular point in time, suppressing all other explanatory variables for clarity of exposition:

$$Unemployment = \beta_0 + \beta_1 \, Irrigated\ Land + \varepsilon \qquad (11)$$

β_1 is the estimated slope coefficient on the irrigated land variable—it represents the marginal effect that irrigated land has on unemployment. The functional form in Equation 4 makes the assumption that the relationship between irrigated land and unemployment is constant over the entire range of possible acreages. However, as discussed previously, there are a number of reasons to believe that this is not the case.

One way to test for a non-constant relationship between irrigated land and unemployment is to estimate the model for different sub-samples of counties based on the amount of irrigated land in each county: if β_1 was found to differ significantly between sub-samples, it would suggest that the relationship between irrigated land and economic health depends on the initial amount of irrigated land in a county.

The Chow test adopts a similar approach by comparing the residual sum of squares (RSS) from the full-sample regression with that from sub-sample regressions based on researcher-specified breakpoint levels of irrigated land. An F-test is used to test the null hypothesis that the RSS is not statistically different between regressions (i.e., there is no structural break). The Chow test relies on the assumptions that the error terms in each regression are independently and normally distributed with the same (homoskedastic) variance. Because the true error variances cannot be observed, their estimates can be obtained from the RSS given in the regressions (Gujarati, 2003):

$$\hat{\sigma}^2_1 = RSS_1 / (n_1 - k) \tag{12}$$

$$\hat{\sigma}^2_2 = RSS_2 / (n_2 - k) \tag{13}$$

The ratio of these two estimates follows the F distribution with $(n_1 - k)$ and $(n_2 - k)$ degrees of freedom in the numerator and denominator, respectively. If the null hypothesis of equal variances in the two subpopulations cannot be rejected, then the Chow test can be used.

One shortcoming of the sub-sample and Chow tests methods is the loss of information in each of the separate regressions due to the smaller sample sizes. Dummy variables provide another way to capture a change in a slope coefficient. Two closely-related dummy variable techniques are piecewise linear regression and spline regression. Piecewise linear models are used when a regression line is broken into a number of line segments, each with its own slope, at points known as *knots* or *thresholds*. Spline models are a restricted form of piecewise linear models, whereby the function is forced to be continuous at the threshold(s).

For example, suppose that the results of a Chow test or some other evidence suggests that a threshold occurs at 20,000 acres. The function to be estimated is:

$$\begin{aligned} E[\textit{Unemployment} \mid \textit{Irrigated Land}] &= \beta_0 + \beta_1(\textit{Irrigated Land}) \text{ if } \textit{Irrigated Land} < 20{,}000 \\ &= \beta_0 + \gamma_1 + \beta_2(\textit{Irrigated Land}) \text{ if } \textit{Irrigated Land} \geq 20{,}000 \end{aligned} \tag{14}$$

Combining these two equations yields:

$$\textit{Unemployment} = \beta_0 + \beta_1 (\textit{Irrigated Land}) + \gamma_1 d_1 + \beta_2 d_1 (\textit{Irrigated Land}) + \varepsilon \tag{15}$$

where $d_1 = 1$ if irrigated land ≥ 20,000. The slopes in the two segments of the line are β_1 and $\beta_1 + \beta_2$, respectively. To make the two segments piecewise continuous, the segments must be forced to join at the threshold values. That is, the endpoint of the first segment must have the same value on the y-axis as the starting point of the second segment:

$$\beta_0 + \beta_1*20{,}000 = \beta_0 + \gamma_1 + (\beta_1 + \beta_2)*20{,}000 \quad (16)$$

This requires restriction of the coefficients so that:

$$\gamma_1 + \beta_2*20{,}000 = 0 \quad (17)$$

Inserting Equation 10 into Equation 8:

$$\textit{Unemployment} = \beta_0 + \beta_1\,(\textit{Irrigated Land}) + \delta_1 d_1\,(\textit{Irrigated Land} - 20{,}000) + \varepsilon \quad (18)$$

The function is actually two functions, one for each segment on the x axis on either side of the threshold. For values of *Irrigated Land* less than 20,000 acres, $d_1 = 0$, giving the polynomial

$$\textit{Unemployment} = \beta_0 + \beta_1\,(\textit{Irrigated Land}) + \varepsilon \quad (19)$$

For values of *irrigated land* above 20,000 $d_1 = 1$, yielding the following polynomial:

$$\textit{Unemployment} = \beta_0 + \beta_1\,(\textit{Irrigated Land}) + \delta_1(\textit{Irrigated Land} - 20{,}000) + \varepsilon \quad (20)$$

Other explanatory variables can be easily incorporated, as can multiple thresholds. Standard measures of significance for regression models are directly applicable, although while the function itself is continuous, its derivatives are not, so that extrapolations of the function beyond the data range to which it is applied are not defined (Speyrer and Ragas, 1991).

Spline functions began appearing in economic applications in the 1970s (Suits, et al., 1978). Empirical applications include the estimation urban population densities (Anderson, 1982), the analysis of housing prices and flood risk (Speyrer and Ragas, 1991), and health status-based risk-adjustment models (Hornbrook et al., 1998). The approach has yet to be used to examine the relationship between irrigated land and rural economic health.

Results and Discussion

The research goal is to advance the measurement of irrigated agriculture's role in the economic health of western rural counties. This is pertinent and timely information for rural counties as their resources transition to urban use. Econometric procedures are used to model the relationship between irrigated land and economic health over time, controlling for other factors that are theorized to influence the economic health of a region. This relationship is then examined for structural breaks in order to examine the existence a threshold level of irrigated land below which so much economic activity is lost and so many economic ties broken that the economy can no longer thrive.

To provide a general overview of the study area, mean values of each of the dependent variables and several relevant variables are displayed in Tables 4 and 5. On average, these counties have seen recent improvements in all four measures of economic health considered here. This is despite a small average reduction in irrigated land. The number of violent crimes in these counties nearly doubled over the period, which is particularly striking given that the U.S. overall experienced a ten percent decrease in violent crimes over the same period.

Table 4: Mean Values of the Dependent Variables and Irrigated Land

	Population	Value of Sales	S-W Index	Unemployment Rate
Early Period	10,363	$143,909	0.69	4.8%
Late Period	10,454	$175,444	0.73	4.0%

Table 5: Mean Values of some Explanatory Variables

	Irrigated Land	Average Farm Size	% Bachelors Degree	% Caucasian	Violent Crimes	% Over 60
Early Period	38,022	1,555 acres	13.1	92.7	15.9	17.1
Late Period	36,050	1,631 acres	16.2	92.4	31.6	17.3

A scatterplot provides a visual representation of the correlation between two variables. While scatterplots do not control for the influence of other variables and thus do not inform the question of causality, they give an idea of the sign of the relationship between two variables and provide motivation for further study. Thus, as a starting point for a more in-depth analysis, the explanatory variable of interest—irrigated land—was plotted against each of the four measures of economic performance considered here (Figure 2).

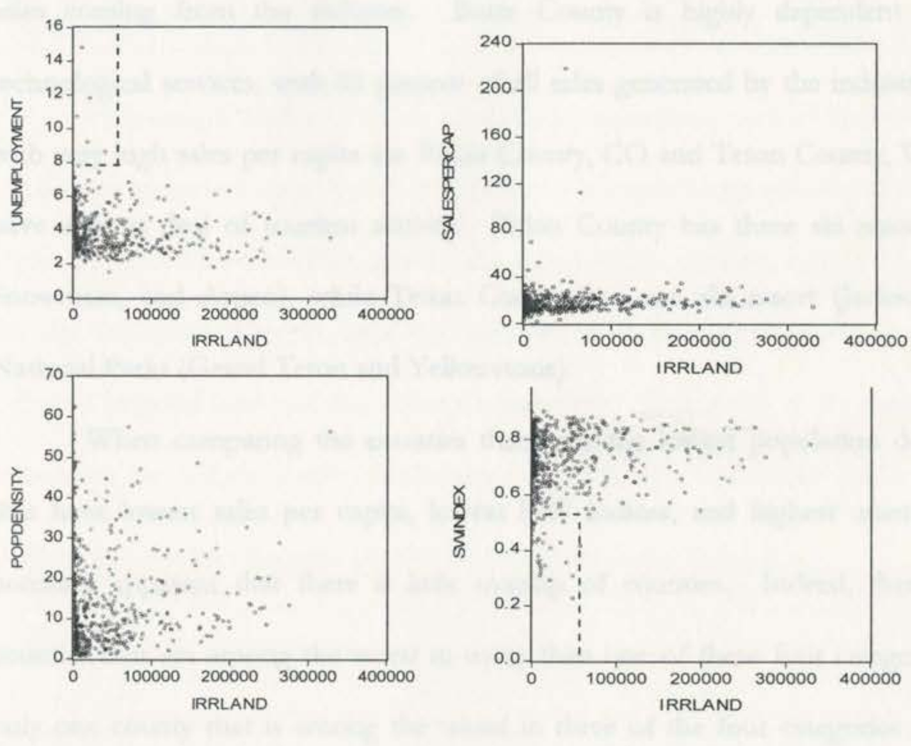

Figure 2: Irrigated Land Plotted against Four Indicators of Economic Health

In line with the first research hypothesis—that irrigated land contributes positively to the economic health of rural counties—the graphs show a positive relationship between irrigated land and population density, industrial diversity, and the value of sales per capita, and a negative relationship between irrigated land and the unemployment rate. The dotted lines in the upper left scatterplot illustrate the fact that all counties with unemployment rates above eight percent have levels of irrigated land below 50,000 acres. Similarly, the dotted lines in the lower right scatterplot illustrate the fact that all of the counties with a S-W index of less than 0.50 have levels of irrigated land below 50,000 acres.

The two outliers that have very high sales per capita are Eureka County, NV and Butte County, ID. Eureka County is highly dependent on mining, with 89 percent of the county's sales coming from the industry. Butte County is highly dependent on scientific and technological services, with 81 percent of all sales generated by the industry. Other counties with very high sales per capita are Pitkin County, CO and Teton County, WY, both of which have a great deal of tourism activity. Pitkin County has three ski resorts (Crested Butte, Snowmass, and Aspen), while Teton County has one ski resort (Jackson Hole) and two National Parks (Grand Teton and Yellowstone).

When comparing the counties that have the lowest population densities with those that have lowest sales per capita, lowest S-W indices, and highest unemployment rates, it becomes apparent that there is little overlap of counties. Indeed, there are only eleven counties that are among the worst in more than one of these four categories (Table 6), and only one county that is among the worst in three of the four categories (McPherson, NE). This reiterates the need to consider multiple measures of economic health. It is interesting to note that eight of the eleven counties have less irrigated land than the study area average.

Table 6: Counties Faring Relatively Poorly in More than One of Four Economic Indicators

County	Population	Value of Sales	S-W Index	Unemployment	Irrigated Land
Conejos, CO	0.0093	$7.80	0.77	6.6 %	59,209
Eureka, NV	0.0028	$218.68	0.39	3.9 %	42,034
Sioux, NE	0.0038	$3.00	0.59	2.8 %	39,926
Hudspeth, TX	0.0066	$10.09	0.64	7.4 %	35,467
McPherson, NE	0.0006	$5.47	0.46	2.4 %	12,574
Willacy, TX	0.0296	$7.40	0.74	9.2 %	10,390
Blaine, NE	0.0007	$5.33	0.58	3.0 %	9,830
Arthur, NE	0.0008	$1.36	0.59	3.4 %	7,755
Golden Valley, MT	0.0020	$7.60	0.64	3.5 %	5,380
Buffalo, SD	0.0044	$13.83	0.45	14.8 %	1,545
Newton, TX	0.0277	$5.77	0.75	7.4 %	303

Following a similar rationale behind the scatterplots, each of the measures of economic health was regressed on irrigated land as the sole explanatory variable (Table 7). Once again there appears to be a positive, albeit weak, relationship between irrigated land and population density, industrial diversity, and the value of sales per capita, and a negative relationship between irrigated land and the unemployment rate. It remains to be seen if this relationship holds once the effects of other explanatory variables have been controlled for.

Table 7: Results when Irrigated Land is the Sole Explanatory Variable

Dependent Variable	Coefficient	Standard Error	Probability
Population	-2.03E-08	1.20E-08	0.0921
S-W Index	1.53E-07	6.56E-08	0.0201
Value of Sales	2.50E-05	4.49E-06	0.0000
Unemployment	-4.33E-06	8.54E-07	0.0000

Model Fit

Heteroskedasticity violates the assumption of classical linear regression that the error terms are drawn from a distribution that has a constant variance. While OLS estimators in the presence of heteroskedasticity remain unbiased and consistent, they are no longer efficient, even with large sample sizes. While there is no universally agreed-upon method of testing for heteroskedasticity, and no way to prove its existence (Studenmund, 2001), White's (1980) test is commonly used. Because White's test detected heteroskedasticity in all four lagged models, White's heteroskedasticity-consistent standard error and variance estimates are used in all models estimated here.

If the explanatory variables in a regression are highly correlated with one another, OLS will still yield unbiased parameter estimates, but the estimates will have large standard errors, making them difficult to estimate with great precision or accuracy and making it difficult to isolate the individual effects of each variable. One indicator of multicollinearity is a high R^2 value but few significant t-statistics. Using this simple method, there was very little evidence of multicollinearity in the models used here.

Another indicator of multicollinearity is high pair-wise correlation among regressors. The correlation coefficient reflects the amount of variability that is shared between two variables, with values of 0.8 or higher signaling a serious problem (Gujarati, 2003). The coefficients of correlation for the explanatory variables used in this study are displayed in Appendix A. There is a high level of correlation between early population and both the concentration of non-farm establishments (0.84) and the urban-rural continuum code (-0.67). Thus, when early population is included in a model, the concentration of non-farm establishments is excluded and the urban-rural continuum code is replaced by the urban adjacency dummy variable, whose correlation with early population is only 0.37.

Structural Stability of the Relationship between Irrigated Agriculture and Economic Health

Three techniques were used to examine the question of a non-constant relationship between irrigated agriculture and rural economic health: Chow tests; separate regressions on sub-samples of counties according to their initial endowment of irrigated land; and spline regression. The results or each are discussed next.

Chow Tests

Using the lagged estimator, a series of Chow tests were performed at four hypothesized break-points. The calculated F-statistics and associated probabilities are displayed in Table 8, where an asterisk indicates a test result that is statistically significant at the five percent level. According to these tests, there is evidence of multiple structural breaks in each equation with the exception of the *S-W Index* equation, for which there is no evidence of a structural break.

Table 8: Chow Breakpoint Test Results

	Population		*S-W Index*		*Value of Sales*		*Unemployment*	
Threshold	**F-stat**	**Prob.**	**F-stat**	**Prob.**	**F-stat**	**Prob.**	**F-stat**	**Prob.**
10,000 acres	5.19	0.0000*	1.50	0.0856	5.42	0.0000*	2.54	0.0003*
20,000 acres	2.87	0.0000*	1.32	0.1683	10.88	0.0000*	1.72	0.0271
30,000 acres	2.62	0.0002*	1.53	0.0746	13.56	0.0000*	1.53	0.0658
40,000 acres	2.50	0.0004*	1.62	0.0519	16.32	0.0000*	1.77	0.0211*
50,000 acres	1.85	0.0143*	1.57	0.0625	1.24	0.2143	1.75	0.0230*

However, based on the results of the F-test method discussed previously, the Chow test is not valid in all cases considered in Table 8. The results of the F-test are displayed in Table 9, where asterisks indicate cases in which the null hypothesis that the Chow test is valid cannot be rejected (i.e., the cases in which the Chow test was determined to be valid). The critical value for the F-test is 1.30 in each case under consideration. Considering only the valid Chow tests (those with asterisks in Table 9), there remains evidence of a breakpoint in the *Population* equation at 50,000 acres and in the *Value of Sales* equation at 20,000 acres.

Table 9: Results of F-test for Validity of the Chow Test

Threshold	*Population*	*S-W Index*	*Value of Sales*	*Unemployment*
10,000 acres	2.07	0.97*	11.1	1.33
20,000 acres	2.68	0.95*	0.11*	1.22*
30,000 acres	1.3	0.49*	193.7	1.65
40,000 acres	1.69	0.42*	176.8	1.86
50,000 acres	0.68*	0.20*	1,452,501	1.87

Separate Regressions on Sub-Samples

Table 10 displays the results of separate regressions run on the same five possible threshold values use previously. The letters refer to the sign of the coefficient on the irrigated land variable, with the first letter representing the sign for those counties with amounts of irrigated land *below* the threshold value, and the second letter representing the sign for those counties with amounts of irrigated land *above* the threshold.

Table 10: Sub-Sample Differences in the Marginal Effect of Irrigated Land

Threshold	Population	S-W Index	Value of Sales	Unemployment
10,000 acres	N, --	-- , --	P , P	-- , N
20,000 acres	-- , --	N, --	-- , P	-- , --
30,000 acres	N, --	N, --	-- , P	-- , N
40,000 acres	N, --	N, --	--, P	-- , --
50,000 acres	N, --	-- , --	-- , --	-- , --

These tests yield results similar to those of the Chow tests, with irrigated land's effect on economic health generally improving at higher levels of irrigated land. With respect to population density and industrial diversity, the marginal effect of irrigated land is generally negative below the thresholds, after which its effect is neutral. With respect to sales per capita, the marginal effect of irrigated land is generally neutral until the threshold is reached, after which it has a positive effect. In the case of unemployment, irrigated land has no effect until the threshold is reached, after which it reduces unemployment.

Spline Regression

A series of spline regressions was run with each of the previously-tested thresholds (Table 11). In contrast to the Chow tests, the strongest evidence of a threshold appears in the *S-W Index* equation. In line with the sub-sample regressions, the 10,000-, 20,000-, and 30,000-acre thresholds were all significant in the *S-W Index* equation, with the sign of the relationship switching from negative to positive at the threshold. The 10,000-acre threshold had the highest individual statistical significance and yielded the best overall model fit. Including combinations of the threshold values in each equation did not reveal any evidence of multiple thresholds. These results held for both the lagged and FE estimators.

Table 11: Spline Regression Results

	Population	S-W Index	Value of Sales	Unemployment
Lagged				
10,000 acres	N , P	N , P	— , —	— , —
20,000 acres	N , P	N , P	— , —	— , —
30,000 acres	— , —	N , P	— , —	— , —
40,000 acres	— , —	— , —	— , —	N , P
50,000 acres	— , —	— , —	— , —	— , —
Fixed Effects				
10,000 acres	— , —	N , P	— , —	N , P
20,000 acres	— , —	N , P	— , —	— , —
30,000 acres	— , —	N , P	— , —	— , —
40,000 acres	— , —	— , —	— , —	— , —
50,000 acres	— , —	N , P	— , —	— , —

Detailed Results for the Lagged Models

Irrigated land was found to have a negative effect on population density until a threshold of 10,000 acres is reached, beyond which irrigated land has a positive effect on population (Table 12). In line with expectations, highway spending and initial population appear to have a positive effect on population density. The percentage of female employees also appears to have a positive effect on population. In rural agricultural counties, females are sometimes a slack labor resource, and if a county has jobs available for female partners, more of the population will be likely to remain in that county. Women's role in child-bearing may also be a factor. The percentage of households headed by married couples also has a weakly positive effect on population, and may have to do with child-rearing.

Average farm size was also found to have a negative influence on population density, which would be expected for a number of reasons. The larger a farm, the less land area that is available for other types of development. Also, larger farms are more likely to experience economies of scale, such that fewer inputs, including labor, are needed for a given level of production. Finally, the larger a farm becomes, the more labor is replaced with physical capital (e.g., tractors). Natural amenity rank was also found to have a negative effect on population density. While this result seems counterintuitive at first glance, higher amenity ranks are given to counties with more bodies of water and more hilly or mountainous terrains; thus, these counties are more likely to have a smaller proportion of land available for development. Taxes were also found to have a negative effect on population density.

Table 12: Some Determinants of Rural County Population Density

Dependent Variable: Population Density				
Explanatory Variable	**Coefficient**	**Standard Error**	**t-Statistic**	**Probability**
Constant	-0.0031	0.0132	-0.2373	0.8125
Irrigated Land**	-3.6E-07	0.0000	-2.8174	0.0050
Irrigated Land – 10,000**	3.5E-07	0.0000	2.6796	0.0076
Highway Spending per Acre**	3.1214	0.4835	6.4553	0.0000
% over 60	-0.0002	0.0001	-1.2226	0.2221
% Bachelor's Degree	-0.0002	0.0001	-1.1832	0.2373
% Married*	0.0190	0.0106	1.7901	0.0740
Natural Amenity**	-0.0011	0.0004	-2.5367	0.0115
% Caucasian	-0.0001	0.0001	-1.2572	0.2093
Northern Plains	-0.0015	0.0018	-0.8224	0.4112
Southern Plains	0.0038	0.0023	1.6264	0.1045
Urban Adjacency	-0.0002	0.0005	-0.4664	0.6411
% Female**	0.0499	0.0191	2.6065	0.0094
Early Population**	0.0000	0.0000	5.4018	0.0000
% Healthcare Establishments	-0.0162	0.0181	-0.8973	0.3700
Tax Revenue per Capita**	-0.0015	0.0005	-2.8791	0.0042
Median Income	0.0000	0.0000	-0.8644	0.3878
Average Farm Size**	0.0000	0.0000	-3.6215	0.0003
S-W Index	-0.0116	0.0115	-1.0027	0.3165
Crime	0.0001	0.0000	1.2582	0.2089
Drought	0.0004	0.0003	1.3199	0.1875
Adjusted R-squared: 0.7573		F-statistic: 83.70 (Probability = 0.0000)		
Log likelihood: 1,745		Sum squared resid: 0.0435		

**Statistically significant, $\varrho<0.05$
*Statistically significant, $\varrho<0.10$

Irrigated land was found to have a weakly positive effect on the value of sales per capita (Table 13). Median income and the number of non-farm establishments per land area were also found to have a positive effect on sales. The percentage of married households, natural amenity rank, and drought were all found to have a negative effect on the value of sales per capita. It may be that married households are more likely to have a non-working member. Again, counties with more natural amenities likely have a greater proportion of land set aside for open space, recreation, and other land uses that generate relatively less economic activity.

Table 13: Some Determinants of Rural County Sales per Capita

Dependent Variable: Value of Sales per Capita				
Explanatory Variable	**Coefficient**	**Standard Error**	**t-Statistic**	**Probability**
Constant	94.0574	43.2984	2.1723	0.0303
Irrigated Land*	1.5E-05	0.0000	1.9176	0.0557
Hwy Spending per Acre	-313.32	231.14	-1.3555	0.1758
% over 60	0.1302	0.1990	0.6543	0.5132
% Bachelor's Degree	-0.1675	0.2422	-0.6913	0.4897
% Married**	-70.7294	33.2666	-2.1261	0.0340
Natural Amenity**	-1.1907	0.4623	-2.5754	0.0103
% Caucasian	0.0154	0.0331	0.4658	0.6416
Northern Plains	-0.1084	1.3161	-0.0824	0.9344
Southern Plains**	6.4943	2.4020	2.7037	0.0071
Ruralness	-0.2607	0.5366	-0.4859	0.6272
% Female	-20.1939	19.8011	-1.0198	0.3083
% Healthcare Establishments	0.4900	15.4853	0.0316	0.9748
Tax Revenue per Capita	2.0426	1.4873	1.3734	0.1702
S-W Index	-78.7489	48.4640	-1.6249	0.1048
Average Farm Size	-0.0002	0.0002	-0.9876	0.3238
Crime	-0.0059	0.0174	-0.3407	0.7334
Unemployment	0.1240	0.1746	0.7101	0.4780
Median Income**	0.0009	0.0003	3.2252	0.0013
Non-Farm Estabs per Acre**	0.0116	0.0037	3.1028	0.0020
Drought**	-1.2063	0.5086	-2.3716	0.0181
Adjusted R-squared: 0.3946		F-statistic: 18.27 (Probability = 0.0000)		
Log likelihood: -1,911		Sum squared resid: 41,571		

**Statistically significant, ϱ<0.05
*Statistically significant, ϱ<0.10

The results in Table 14 suggest that the relationship between irrigated land and industrial diversity depends on the initial level of irrigated land: at levels below 10,000 acres, irrigated land appears to stifle industrial diversity, while at levels above 10,000 acres, additional irrigated land appears to enhance industrial diversity. It could be that above 10,000 acres, there is enough irrigated agricultural activity to support the co-location of suppliers and downstream businesses (e.g., food processing firms, animal feedlots). As expected, ruralness was found to reduce industrial diversity. The density of non-farm establishments, the proportion of Caucasian residents, and the proportion of female employees were all found to have a positive effect on industrial diversity. Women differ from men in their employment and consumption patterns, so that a greater proportion of women employees may generate demand for a wider array of goods and services while providing labor for a wider array of industries.

Table 14: Some Determinants of the Industrial Diversity of Rural Counties

Dependent Variable: S-W Index				
Explanatory Variable	**Coefficient**	**Standard Error**	**t-Statistic**	**Probability**
Constant	0.4441	0.1391	3.1919	0.0015
Irrigated Land**	-4.1E-06	0.0000	-3.7956	0.0002
(Irrigated Land – 10,000 acres)**	4.2E-06	0.0000	3.7676	0.0002
Highway Spending per Acre	5.5E-07	0.0000	0.1973	0.8437
% over 60	-1.4E-05	0.0000	-1.5861	0.1133
% Bachelor's Degree	-7.8E-06	0.0000	-0.7462	0.4559
% Married	-0.0002	0.0013	-0.1740	0.8620
Natural Amenity	0.0011	0.0041	0.2725	0.7854
% Caucasian**	1.7E-05	0.0000	4.2484	0.0000
Northern Plains	-0.0190	0.0122	-1.5518	0.1213
Southern Plains	-0.0059	0.0212	-0.2775	0.7815
Ruralness**	-0.0218	0.0034	-6.4086	0.0000
% Female**	0.0085	0.0018	4.7266	0.0000
% Healthcare Establishments	0.0001	0.0004	0.3605	0.7186
Tax Revenue per Capita	-0.0001	0.0001	-1.6045	0.1092
Average Farm Size	-9.4E-07	0.0000	-0.4016	0.6881
Crime*	-0.0002	0.0001	-1.7826	0.0752
Non-Farm Estabs per Acre**	0.0001	0.0000	3.3272	0.0009
Drought	-0.0040	0.0028	-1.4335	0.1523
Adjusted R-squared: 0.4949		F-statistic: 29.85 (Probability = 0.0000)		
Log likelihood: 644.42		Sum squared resid: 2.74		

**Statistically significant, ϱ<0.05
*Statistically significant, ϱ<0.10

Irrigated land appears to have a negative effect on unemployment (Table 15). According to these estimates, a one percent decrease in irrigated land would lead to a 0.0002 percent increase in the unemployment rate. In line with the findings of Malizia and Ke (1993), the proportion of residents with at least a Bachelor's degree and the proportion of female workers were also found to reduce unemployment. Other variables that were found to reduce unemployment were the proportion of residents over 60, proportion of married households, and median income. The higher the proportion of residents over 60, the lower the proportion of residents seeking employment for a given number of establishments. A higher proportion of married households may also be associated with a lower proportion of residents seeking employment as one member of the couple acts as a stay-home parent. The negative coefficient on median income suggests that a concentration of high-wage industries has a demand spillover effect on the labor market, in line with the results of Partridge and Rickman (1997). Finally, ruralness also appears to reduce unemployment; thus, while being more rural means having a lower population and is generally associated with lower sales and industrial diversity, it appears to have the benefit of reducing unemployment.

The only variables that were found to exacerbate unemployment were crime, drought, and natural amenity rank (at the ten percent level of significance). Although the latter was statistically significant at the ten percent level, this result is in line with the results of the *Value of Sales* equation—counties with a higher natural amenity rank may have fewer employment opportunities due to a higher proportion of land being set aside as open space. Additionally, these counties likely have more outdoor recreational jobs, which tend to be seasonal rather than year-round.

Table 15: Some Determinants of Rural County Unemployment

Dependent Variable: Unemployment Rate				
Explanatory Variable	**Coefficient**	**Standard Error**	**t-Statistic**	**Probability**
Constant	14.8592	1.3733	10.8201	0.0000
Irrigated Land**	-2.8E-06	0.0000	-3.8443	0.0001
Hwy Spending per Land Area	3.9E-05	0.0001	0.7113	0.4772
% over 60**	-0.0006	0.0002	-3.1407	0.0018
% Bachelor's Degree**	-0.0007	0.0001	-5.0617	0.0000
% Married**	-0.0476	0.0127	-3.7539	0.0002
Natural Amenity*	0.0901	0.0544	1.6583	0.0979
% Caucasian	-0.0001	0.0001	-0.8766	0.3811
Northern Plains	-0.3654	0.1866	-1.9580	0.0508
Southern Plains	-0.2479	0.2778	-0.8922	0.3727
Ruralness**	-0.1182	0.0445	-2.6583	0.0081
% Female**	-0.0575	0.0208	-2.7596	0.0060
Non-Farm Estabs per Acre	-0.0005	0.0003	-1.5630	0.1187
% Healthcare Establishments	0.4022	1.8664	0.2155	0.8295
Tax Revenue per Capita	0.0397	0.0431	0.9209	0.3575
Average Farm Size	0.0000	0.0000	-0.6586	0.5104
S-W Index	-0.2133	0.9763	-0.2185	0.8271
Median Income**	-0.0001	0.0000	-4.5226	0.0000
Crime**	0.0043	0.0017	2.5663	0.0106
Drought*	0.0563	0.0326	1.7263	0.0849
Adjusted R-squared: 0.4463		F-statistic: 23.48 (Probability = 0.0000)		
Log likelihood: -708.85		Sum squared resid: 448.87		

**Statistically significant, ϱ<0.05
*Statistically significant, ϱ<0.10

Detailed Results for the Fixed-Effects Models

When the FE estimator is used, irrigated land is not found to have a statistically significant effect on population density (Table 16). The variables found to have a positive effect on population density were highway spending, percent female, early population, and crime, all of which are in agreement with the findings of the lagged estimator, with the exception of percent Caucasian, which was not significant previously.

Table 16: FE Estimation of Rural County Population

Dependent Variable: Population Density				
Explanatory Variable	**Coefficient**	**Standard Error**	**t-Statistic**	**Probability**
Constant	0.0078	0.0173	0.4541	0.6499
Irrigated Land	-2.0E-08	0.0000	-0.9633	0.3359
Highway Spending per Acre**	2.1917	0.3569	6.1407	0.0000
% over 60	-0.0005	0.0010	-0.5234	0.6009
% Bachelor's Degree	-0.0047	0.0049	-0.9460	0.3446
% Married	0.0032	0.0158	0.2045	0.8381
% Caucasian**	-0.0076	0.0090	-0.8455	0.3983
% Female**	0.0417	0.0181	2.3042	0.0216
% Healthcare Establishments	-0.0078	0.0213	-0.3655	0.7149
Tax Revenue per Capita	-0.0001	0.0005	-0.1406	0.8883
Median Income**	-5.9E-07	0.0000	-2.1215	0.0344
Average Farm Size	-4.5E-07	0.0000	-1.0674	0.2864
S-W Index**	-0.0136	0.0066	-2.0739	0.0386
Crime**	0.0001	0.0000	2.4186	0.0160
Early Population**	7.4E-07	0.0000	4.6074	0.0000
Drought	-2.4E-05	0.0001	-0.1970	0.8439
Adjusted R-squared: 0.8142		F-statistic: 8.96 (Probability = 0.0000)		
Log likelihood: 3,981		Sum squared resid: 0.0296		

**Statistically significant, ρ<0.05

When the FE estimator is used, irrigated land is no longer found to have a statistically significant effect on the value of sales per capita (Table 17). Variables that were found to have a positive effect were median income and non-farm establishments, both of which are in line with the lagged estimator. In line with the findings of Drabenstott and Smith (1995), tax revenue per capita was found to have a (weakly) positive effect on sales per capita. In line with the results of the lagged estimator, the percentage of married households was found to negatively affect the value of sales per capita.

Table 17: FE Estimation of Rural County Sales

Dependent Variable: Value of Sales per Capita				
Explanatory Variable	**Coefficient**	**Standard Error**	**t-Statistic**	**Probability**
Constant	67.2414	29.1574	2.3062	0.0215
Irrigated Land	2.4E-06	0.0000	0.0758	0.9396
Highway Spending per Land Area	-184.07	179.9385	-1.0229	0.3069
% over 60	0.3616	0.7981	0.4530	0.6508
% Bachelor's Degree	5.6368	6.1574	0.9154	0.3604
% Married**	-29.78	14.9524	-1.9914	0.0470
% Caucasian	0.3865	5.6569	0.0683	0.9456
Ruralness	-0.7519	0.8640	-0.8703	0.3846
% Female*	-34.79	20.8587	-1.6680	0.0960
% Healthcare Establishments	3.0906	18.1697	0.1701	0.8650
Tax Revenue per Capita*	2.4694	1.3381	1.8454	0.0656
Unemployment	-0.1520	0.1756	-0.8656	0.3871
Non-Farm Estabs per Acre**	5,029	1480.9240	3.3956	0.0007
Early S-W Index	-38.63	26.6119	-1.4516	0.1473
Average Farm Size	-0.0004	0.0004	-0.9360	0.3498
Crime	0.0056	0.0133	0.4175	0.6765
Median Income**	0.0007	0.0003	2.4314	0.0154
Drought	-0.0147	0.1770	-0.0829	0.9340
Adjusted R-squared: 0.2361		F-statistic: 1.56 (Probability = 0.0000)		
Log likelihood: -3,394		Sum squared resid: 40,979		

**Statistically significant, $\varrho<0.05$
*Statistically significant, $\varrho<0.10$

In agreement with the results of the lagged estimator, irrigated land was found to have a negative effect on industrial diversity until a threshold of 10,000 acres is reached, after which irrigated land enhances industrial diversity (Table 18). Also in agreement with the lagged estimator, the proportion of Caucasian residents and the proportion of female workers were found to enhance industrial diversity. The density of non-farm establishments was additionally found to enhance economic diversity, which would be expected. Unexpectedly, the FE estimator found a positive relationship between crime and industrial diversity. In agreement with the lagged estimator, the percentage of the population over 60, ruralness, and tax revenue per capita were all found to reduce industrial diversity.

Table 18: FE Estimation of Rural County Industrial Diversity

Dependent Variable: S-W Index				
Explanatory Variable	**Coefficient**	**Standard Error**	**t-Statistic**	**Probability**
Constant	0.3549	0.1199	2.9601	0.0032
Irrigated Land**	-3.0E-06	0.0000	-2.0459	0.0413
Irrigated Land – 10,000acres**	3.2E-06	0.0000	2.0198	0.0440
Highway Spending per Land Area	-2.0257	1.4323	-1.4143	0.1579
% over 60**	-0.0152	0.0045	-3.4037	0.0007
% Bachelor's Degree	-0.0163	0.0515	-0.3175	0.7510
% Married	-0.0163	0.0996	-0.1633	0.8704
% Caucasian**	0.2286	0.0558	4.0937	0.0001
Ruralness**	-0.0143	0.0040	-3.5618	0.0004
% Female**	0.7087	0.1492	4.7494	0.0000
% Healthcare Establishment	0.1739	0.1661	1.0470	0.2956
Tax Revenue per Capita*	-0.0122	0.0064	-1.9011	0.0579
Average Farm Size	-1.6E-06	0.0000	-0.7222	0.4705
Crime**	0.0003	0.0001	2.0118	0.0448
Non-farm Estabs per Acre**	55.6493	14.0319	3.9659	0.0001
Drought	-0.0003	0.0010	-0.3109	0.7560
Adjusted R-squared: 0.5155		F-statistic: 2.93 (Probability = 0.0000)		
Log likelihood: 1,835		Sum squared resid: 1.8089		

**Statistically significant, $\varrho<0.05$
*Statistically significant, $\varrho<0.10$

In line with the results of the lagged estimator, the FE estimator found irrigated land to have a negative effect on unemployment, but only once the 10,000-acre threshold is passed (Table 19). Also in line with results of the lagged estimator, median income, ruralness, and the proportion of female workers were all found to reduce unemployment. Non-farm establishments and tax revenue per capita were both found to have a weakly negative effect on unemployment. Crime was the only variable that was found to exacerbate unemployment.

Table 19: FE Estimation of Rural County Unemployment

Dependent Variable: Unemployment				
Explanatory Variable	Coefficient	Standard Error	t-Statistic	Probability
Constant	23.3167	3.8339	6.0817	0.0000
Irrigated Land**	-0.0001	0.0000	-2.2148	0.0273
Irrigated Land - 10,000acres**	0.0001	0.0000	2.2752	0.0233
Highway Spending per Acre	26.2518	73.1804	0.3587	0.7200
% over 60	-0.2361	0.1988	-1.1874	0.2357
% Bachelor's Degree	-2.6915	1.8021	-1.4935	0.1360
% Married**	-10.6578	4.2704	-2.4958	0.0129
% Caucasian	1.7255	2.4194	0.7132	0.4761
Ruralness**	-0.3464	0.1011	-3.4253	0.0007
% Female**	-17.2445	5.0370	-3.4236	0.0007
Non-Farm Estabs per Acre*	-1,430	727.58	-1.9648	0.0500
% Healthcare Establishments	-3.5414	5.0657	-0.6991	0.4848
Tax Revenue per Capita*	-0.1667	0.0993	-1.6782	0.0940
Average Farm Size	0.0001	0.0001	0.8708	0.3843
S-W Index	-0.6530	1.2933	-0.5049	0.6139
Median Income**	-0.0002	0.0000	-3.5214	0.0005
Crime**	0.0190	0.0050	3.8439	0.0001
Drought	0.0248	0.0322	0.7714	0.4409
Adjusted R-squared: 0.3326		F-statistic: 1.90 (Probability = 0.0000)		
Log likelihood: -1,688		Sum squared resid: 1,554		

**Statistically significant, $\varrho<0.05$

*Statistically significant, $\varrho<0.10$

Conclusions

Regression analysis was performed on data from 568 rural Inter-Mountain West counties to assess the role of irrigated agriculture in regional economic health as measured by population density, value of sales per capita, industrial diversity, and unemployment rate. When the lagged estimator was used, irrigated land was found to enhance population density and industrial diversity once a threshold of 10,000 acres is surpassed. Irrigated land was also found to enhance sales per capita and reduce unemployment. When the FE estimator was used, irrigated land was not found to have a statistically significant effect on population density or sales per capita, but was found to increase industrial diversity and reduce unemployment once a threshold of 10,000 acres was reached.

The strongest evidence of a structural break in the relationship between irrigated land and economic health appears at the 10,000 acres threshold level, with irrigated land becoming (more) beneficial once this threshold has been reached. Thus, counties that are close to this threshold may want to discourage additional transfers or have an alternative development plan in place prior to a transfer. Because there was also some evidence of a threshold at 20,000 acres, counties near this threshold may also have particular cause for concern when considering additional water transfers. Table 20 lists the number of counties by state which are close to each of these thresholds. The first column lists the states, while the second column lists the number of counties in each state that are just above the 10,000-acre threshold and the fourth column lists those that are just above the 20,000-acre threshold. The fourth column lists the sum of the counties in each state that are close to one of the two thresholds, while the last column lists this sum as a proportion of all rural counties in each state that were included in the study area (i.e., those with positive levels of irrigated land).

Table 20: Counties Close to Threshold of 10,000 Irrigated Acres

State	Between 10,000 and 15,000 Irrigated Acres	Between 20,000 and 25,000 Irrigated Acres	Sum	Sum as % of all Rural Counties in the State with Irrigated Land
AZ	0	0	0	0%
CO	2	3	5	12%
ID	1	0	1	4%
KS	7	3	10	15%
MT	5	1	6	13%
ND	2	1	3	11%
NE	4	3	7	9%
NV	0	0	0	0%
OK	3	2	5	11%
SD	3	1	4	9%
TX	6	6	12	9%
UT	2	0	2	12%
WY	1	0	1	6%
Total	**36**	**20**	**89**	**10%**

Notes, Limitations, and Future Opportunities

. Rural economic health has complex economic, social, institutional, technical, political, and geographic causes, which makes it difficult to isolate the contribution of irrigated agriculture. The analysis would benefit from greater attention to the possibility of spatially-correlated error terms. While the possibility of spatial dependence was indirectly addressed via inclusion of the ERS urban-rural code, which provides information on a county's neighbors, and r egional dummies, which c ontrol for f actors that may affect a group of counties simultaneously, the issue was not specifically examined or directly addressed.

NASS' definition of *Irrigated Land* includes all land watered by any artificial or controlled means. This includes supplemental, partial, and pre-plant irrigation, with each acre being counted only once, regardless of the number of times it was irrigated or harvested. Livestock lagoon waste water distributed by sprinkler or flood systems is also included in the definition. A more precise definition of irrigated land would likely yield more precise results.

Most counties contain both rural and urban areas, and some communities in a county may struggle while other communities in the same county thrive, distinctions that are obscured by county-level data. Unfortunately, the lack of community-level data and the difficulties involved in defining a "community" hinder such detailed analysis. Studies involving more than a single state must usually rely heavily on federal data which are typically collected and reported at the county level. A study of smaller scope but greater regional detail may improve both the accuracy of the research and its applicability to individual communities. Fortunately, the use of panel data makes any less than ideal assumptions less egregious. For example, any flaws in the rural/urban designations will affect all counties in the study area, such that comparisons across all counties over time remain valid and informative.

The economic contribution of irrigated agriculture depends largely on crop prices, which can be highly variable. The use of panel data can partially control for this effect by including data from a large cross-section of counties from more than one time period, making it possible to examine the economic contribution of irrigated agriculture apart from the market conditions in a particular year or the particular crop being grown. Nonetheless, the time-series used here is very short; it would be beneficial to extend the analysis to include additional time periods to examine the robustness of the results found here.

CHAPTER 3: WATER USE IN THE WEST: HOUSEHOLDS' PERCEPTIONS AND PREFERENCES

Water supplies in the western U.S. are quite scarce and often over-appropriated, heightening stakeholders' concerns about future water availability and often spurring contentious debate (Knapp et al., 2003). In the face of water scarcity, decisions must be made about water allocation, supply firming, and capital investment. To better direct available resources, water utilities and policymakers need information about consumer acceptance, satisfaction, and willingness to pay (Vloerbergh et al., 2007). Implicitly, public policy decisions should be also consistent with public attitudes and preferences.

Yet very little has been researched or written about the preferences that western households have for addressing water scarcity. Western households' preferences for addressing water scarcity and their WTP for various water supply initiatives have not been addressed by the literature. Few studies have attempted to measure public knowledge about the environment (Arcury and Johnson, 1987), and even fewer have focused on public knowledge about water. Those that have are limited to student populations (Mills, 1983; Alcorn and Heal, 2009).

A better understanding of public attitudes and preferences for water use and reallocation can help public water utility managers and policymakers develop water initiatives that are consistent with public preferences, which may in turn minimize controversies related to potential management alternatives (Loker, 1996). Furthermore, households' preferences for paying for various water initiatives may be conditional on their knowledge of water supply, allocation and institutions. Quantifying the relationship between water knowledge and willingness to pay (WTP) is important from research, forecasting, and fund-raising perspectives. An initial exploration of the relationship between water knowledge and WTP may assist researchers in designing future studies. If knowledge is an important factor in explaining the variation in households' WTP, water planners and other officials may choose to influence household behavior through education. Benchmarking public knowledge of water resource issues will identify water knowledge gaps and uncover educational opportunities.

Study Purpose and Approach

The goal of this research is to better understand the preferences that western households have for addressing water needs against a backdrop of increasing scarcity. Specifically, this study addresses the following three topics:

1. What are western households willing to pay to resolve water scarcity and which factors influence willingness to pay? Estimates of median willingness-to-pay (WTP) may assist in water resource planning. Specifying a WTP function will identify some of the determinants of WTP—an important consideration when trying to secure funding for water initiatives—and will allow median WTP estimates to be tailored to a specific populace.
2. In addition to providing pecuniary information, WTP serves as a proxy for preferences for various water initiatives, which will vary across households due to heterogeneity in attitudes and demographic characteristics. Particular interest is focused on water knowledge because it is a factor that can potentially be influenced by water managers, policymakers, and other community leaders.

Conventional wisdom suggests that improving knowledge enables better decisions and more efficient use of resources, but increased knowledge can have unexpected results. For instance, water smart readers, designed to decrease household water use by providing household members with real-time information about their water usage, have been shown to actually *increase* water use (Kenney et al., 2008).

3. What are western households' preferences among strategies to address scarcity? Initiatives that might be used to address scarcity include water conservation, re-use, re-allocation and capital investment. No previous study considers the preferences that western households have among these alternatives. These preferences are revealed by examining households' preferred allocation of a fee across eight water initiatives, as revealed by survey responses.

The remainder of this chapter is organized as follows: In the first section, an analytical framework is developed with individual preferences for water management alternatives giving rise to willingness to pay and an observed statistical model. This is followed by a discussion of the specific methodology and data used in this study. The results are then displayed and discussed. The last section concludes and provides some opportunities for future research.

Analytical Framework

This research seeks to uncover households' preferences for meeting water scarcity in the western U.S. One means of gauging household preferences is to examine their stated preferences for hypothetical water initiatives—specifically, whether they would be willing to pay a fee in support of the initiatives. An individual's WTP serves as a proxy for preferences in the sense that if an individual is willing to pay more for a particular good or service than for another, then the individual garners more utility from that good or service, and thus has greater preference it (and vice versa). Estimates of median WTP using stated preference approaches provide an idea of size of fee that the majority of the population could be expected to support. When this amount is not sufficient to cover program costs, water managers are certain to ask how WTP might be increased. The research approach adopted here is to 1) elicit WTP using a dichotomous choice stated preference approach, 2) estimate a WTP function via a logit model, and 3) estimate median WTP using Hanemann's (1984) approach.

The link between WTP and preferences can be revealed by considering the consumer's utility maximization problem. Following Hanemann and Kanninen (1999), individuals have preferences for various goods and services whose consumption is denoted by the vector $\boldsymbol{x}$. If these preferences have the necessary properties[12], they may be represented mathematically by a utility function, $U(\boldsymbol{x})$. The individual's problem is then to maximize $U(\boldsymbol{x})$ subject to a budget constraint based on the individual's disposable income, M, and the prices of the goods and services, which comprise the vector $\boldsymbol{p}$. Consumers' preferences are assumed to be locally non-satiated such that the budget constraint is binding:

$$\boldsymbol{px} = M \tag{21}$$

Viewing water initiatives as consumer goods, residents decide whether or not to support (consume) water initiatives based on perceived benefits and costs of the initiatives. Because the perceived benefits of water initiatives are uncertain, residents are assumed to operate within the framework of a random utility model (RUM). In the standard deterministic RUM (McFadden, 1974), an individual associates utilities with each of the choices available to

[12] These properties include completeness, transitivity, continuity, local non-satiation, and convexity (Jehle and Reny, 2000, pp. 6-11).

him or her and chooses the one that maximizes utility. The standard inference problem is to learn the distribution of preferences from data on the choices and covariates of a random sample of decision makers. The RUM for one individual can be defined as follows:

$$u = v(\boldsymbol{p}, M, \boldsymbol{z}) + \varepsilon \tag{22}$$

where v is an observable component of indirect utility when consuming a particular bundle of goods; $\boldsymbol{z} = z_1, z_2, \ldots, z_K$ is a vector of K characteristics that are hypothesized to influence the utility derived from the bundle of goods; and ε is an additive component of utility that is unobserved by the researcher.

Hanemann (1984) demonstrated the connection between a linear indirect utility function (such as in Equation 22) and the economic concept of WTP using a dichotomous choice valuation question. Let x_i^0 represent the current bundle of goods and services consumed by individual i. Now suppose the individual is given the possibility of changing from the base case consumption bundle to the alternative x_i^1, which includes the water initiatives under consideration. If the individual is asked whether or not he or she would be willing to pay a fee amount A for the change, the individual answers "yes" if and only if the utility received from the new bundle exceeds that of the base case. This situation can be represented mathematically as $v(x_i^1, \boldsymbol{z}, p, M_i - \mathrm{A}) \geq v(x_i^0, \boldsymbol{z}, p, M_i)$.

If A is chosen carefully, there will be variation across individuals in the choice of whether or not to pay the fee. Some of this variation can be explained by heterogeneity in demographic and attitudinal characteristics across individuals. However, an empirical model of WTP will not predict all choices with certainty. Because an individual is bounded by their water knowledge and the finite amount of time they have to make choices, errors might be made in their choices. An individual's choices may even contain an element of randomness, especially in the case of hypothetical choices, such as those respondents are asked to make in the present study. Additionally, it is not possible for researchers to measure all relevant components of **z**. Thus, within the sample population, the probability of observing a "yes" response to the WTP question can be represented as:

$$\Pr[yes] = \Pr[v(x^1, \mathbf{z}, p, M - \mathrm{A}, \varepsilon) \geq v(x^0, \mathbf{z}, p, M, \varepsilon) \tag{23}$$

$$= \Pr(\Delta v < \varepsilon)$$

$$= 1 - G_\varepsilon(\Delta v)$$

where ε is the stochastic component of preferences; Δv is the difference $v(x^1, \mathbf{z}, p, M - \mathrm{A}) - v(x^0, \mathbf{z}, p, M)$; and G_ε is the probability function for the error ε (Watanabe and Asano, 2009). Specifying an extreme value distribution for ε yields the logit model, which is estimated using the maximum likelihood method. The specific functional form in which parameters are estimated is:

$$P(yes)_i = 1 - [1 + \exp(\beta_0 + \beta_1 \mathrm{A} + \beta_2 z_2 + \ldots + \beta_j z_j)]^{-1} + \varepsilon \tag{24}$$

The parameter estimates obtained by estimating Equation 24 suggest the relative importance that knowledge, attitudes, and demographics play in funding the hypothetical water initiatives considered here, fulfilling one of the primary objectives of the study.

Deriving Median WTP from the Logit Model

The dichotomous choice response does not reveal an individual's true WTP—only whether it falls above or below the offered amount. However, the median WTP and the marginal effects of the explanatory variables on median WTP can be calculated using the parameter estimates from Equation 24. Hanemann (1984) demonstrated that the median

WTP of the sample can be obtained by inserting the mean value of each explanatory variable (with the exception of randomly selected fee amount) into the following expression:

$$\text{Median WTP} = [\beta_0 + \beta_2 z_2 + \ldots + \beta_J z_J] / |\beta_1| \qquad (25)$$

Using the Krinsky-Robb bootstrap technique outlined in Loomis et al. (1991), a confidence interval around the median net WTP can be then be constructed. Median WTP estimates can be tailored to a specific populace and can be used to obtain an estimate of aggregate WTP. Contingent valuation analyses have traditionally calculated the aggregate WTP by multiplying either the mean or median WTP by the total number of households in the population. However, such aggregation is only valid in the absence of any sampling frame bias (Bateman et al., 2002), which is not likely the case presently.

Marginal Effects

Reporting the marginal effects of the explanatory variables is an important step in satisfying the study objectives, as they represent the effect that a one-unit change in each of the variables has on WTP. In non-linear regression models, such as the logit model, coefficient estimates cannot be interpreted as marginal effects. The marginal effect of the fee amount (A) on the probability of a "yes" response to the WTP question can be calculated by inserting the parameter estimates and sample means into the following equation (Greene, 2003, p. 668):

$$dP(yes)/dA = \beta_1 \left[\frac{\exp(\beta_0 + \beta_1 * A + \beta_2 * z_2 + \ldots + \beta_N * z_N)}{\{[1 + \exp(\beta_0 + \beta_1 * A + \beta_2 * z_2 + \ldots + \beta_N * z_N)]^2\}} \right] \qquad (26)$$

The marginal effect of the fee amount is expected to be negative.

As demonstrated by Loomis (1987) and Cameron (1988), the marginal effect of the remaining explanatory variables on median WTP can be determined by dividing each variable's parameter estimate by the absolute value of the parameter estimate for the fee amount. For example, the marginal effect of water knowledge on WTP is calculated as:

$$\mathrm{dWTP}/\mathrm{d}(\textit{Water Knowledge}) = \frac{\beta_2}{|\beta_1|} \tag{27}$$

All marginal effects are reported in the Results section of the chapter.

<u>*Water Knowledge*</u>

Of particular interest is how the variation in WTP can be explained by heterogeneity in water knowledge among households. To provide additional insight into the relationship between water knowledge and WTP, separate WTP functions can be estimated for those individuals with high self-reported water knowledge scores and those with low self-reported water knowledge scores. Comparisons of the coefficients across the two groups do not represent true differences in preferences because estimates in random parameters logit models are confounded with the variance of the random term in the consumer utility function. However, the WTP estimates can be compared across the groups since WTP estimates are ratios of attribute parameters and price, and thus do not confound with the variance of the random term in the random utility function (Gao and Schroeder, 2008). To illustrate, a group of households with low water knowledge may have a median WTP of:

$$\text{Median WTP}^{L} = [\beta_0^{\,L} + \beta_2^{\,L}(\textit{Water Knowledge}_L) + \ldots + \beta_J^{\,L}(z_J)]/|\beta_1^{\,L}| \tag{28}$$

Meanwhile, a group of households with high water knowledge may have a median WTP of:

$$\text{Median WTP}^{H} = [\beta_0^{\,H} + \beta_2^{\,H}(\textit{Water Knowledge}_H) + \ldots + \beta_J^{\,H}(z_J)]/|\beta_1^{\,H}| \tag{29}$$

The divergence in WTP between the two groups may signal potential gains from investments in water knowledge, represented by *D*WTP = Median WTP^{H} - Median WTP^{L}.

This section demonstrated how a dichotomous choice question can be used to estimate a WTP function, how the parameter estimates can be used to calculate median WTP for the sample population (Equations 24 and 25), and how aggregate WTP can be inferred from this estimate. The section also demonstrated how the influence of water knowledge on WTP can be further evaluated by estimating separate WTP functions for those with different levels of self-reported water knowledge. The next section describes the WTP question, the explanatory variables that comprise the vector **z**, and the data collection methodology.

Methodology and Data

Non-market valuation can be used to derive estimates of the economic value of goods and services in situations where market prices are absent or distorted—such as the market for water-related goods and services (Young, 2005). Proxying household preferences using a WTP approach requires a representative sampling of households. W hile public hearings are a common method of synthesizing citizen preferences, opinions obtained from these meetings tend to be less representative of the public than those obtained via a questionnaire (Gundry and Heberlein, 1984; Haider and Rasid, 2002). Mahler et al. (2004) used a questionnaire to gain a representative view of public awareness, attitudes, and priorities relating to water quality issues in the Pacific Northwest. A similar approach is adopted here but with a wider study area, larger sample size, and greater emphasis on water quantity and allocation. The study area includes the 17 westernmost states of the continental U.S., where water allocation is a particularly important topic due to rapid population growth and generally less abundant water supplies. Region-wide research allows values and attitudes to be assessed for a broader constituency, ensuring that both traditional and non-traditional stakeholders are included in the process, thus affording a wider perspective on western water issues and allows a broader generalization of results.

Focus groups were conducted in selected regions of the study area to identify water issues of high priority and to aid the development of the questionnaire. The questionnaire was then used to uncover western households' perceptions and preferences regarding water allocation and management and their willingness to pay a fee in support of a number of water initiatives. The questionnaire was developed by an interdisciplinary team of researchers at Colorado State University and was further refined by pretesting with a small sample of individuals. The questionnaire contained a map of the continental U.S., with the 17-state study area highlighted and defined as "the west" for the purposes of the study.

. The survey was administered by Survey Sampling International (SSI), a private firm specializing in sampling, programming, and administering Internet surveys. Internet-based surveys allow researchers to more easily reach respondents in far-spread geographical areas and boost response rates by allowing respondents to log onto a website at their convenience and complete the survey on-line without having to re-package and send a paper survey. The pool of potential respondents is made up of individuals who have signed up ahead of time with SSI to participate in surveys, which presents a potential source of sampling frame bias. The sample selection methodology adopted by Survey Sampling International involves the following steps:

1. The total population is identified and then sorted by Postal Code.
2. The total population is divided by the desired sample size to create a selection interval. A computer program generates a random number less than the selection interval to provide a starting point. Questionnaires are then sent randomly to prospective respondents until the desired sample size is achieved.

3. The resulting sample is sorted randomly before e-mailing, so that when samples are "batch" e-mailed, each batch represents a smaller version of the entire sample, virtually identical to every other batch in demographics, geography, etc.

A total of 203,750 e-mail invitations were sent between May and June of 2008. Of the 6,883 people who opened the e-mail, 6,250 completed the questionnaire.

Dependent Variable: The Dichotomous Choice

While a variety of question formats have been used to elicit WTP values, research has shifted toward use of the dichotomous choice (DC) format (Hanemann and Kaninnen, 1999), whereby a hypothetical program is described to the respondent, after which the respondent is asked whether or not he or she would pay a particular price to support the program. The two main arguments for using DC as opposed to open-ended questions are simplicity for respondents and reduced incentives for strategic responses (Hoehn and Randall, 1987). While the DC format is less efficient than an open-ended format, this only becomes an issue with small sample sizes, which is not the case presently.

Adopting the DC methodology, respondents are asked whether they are willing to pay fee—which varied randomly across respondents from $5 to $25 in five-dollar increments—on their water bill during the summer months to fund programs designed to increase the supply of water and reduce the demand for water. Respondents are told that this fee would be used to support eight such water initiatives. The cost of the initiatives and the apportionment of funds are not specified. The question was worded as follows:

"Water providers might consider increasing water rates in order to find new sources of water, to pay for water conservation programs, or to help with problems that may arise as water is shifted to cities from other areas. Would you pay an additional $A per month on your water bill during the summer months if the fee was divided among the following programs?"

1. To implement programs and technology to reduce household water consumption.
2. To construct a reservoir for water storage.
3. To create a system to reuse household waste water for watering public landscapes.
4. To set aside water for wildlife habitat in and around nearby streams.
5. To help keep irrigated farms in production.
6. To make infrastructure improvements in rural communities as compensation for water being transferred to cities.
7. To set aside water for public water-based recreation.
8. To provide subsidies on water-efficient appliances.

Survey respondents' answers to the WTP question serve as the dependent variable listed on the left-hand side of Equation 24, with responses of "yes" given a value of one and responses of "no" given a value of zero. These responses were then regressed on the set of explanatory variables. In addition to the size of the proposed fee, respondents' likelihood of answering "yes" to the WTP question may also depend on 1) their knowledge of water institutions; 2) their attitudes about water scarcity, conservation, and government jurisdiction; and 3) their demographic characteristics, each of which is described next.

Explanatory Variable: Western Households' Water Knowledge

It is hypothesized that western households' responses to the DC WTP question depends on their knowledge of water institutions. Water knowledge is a potentially important explanatory variable not only because it may explain the variation in stated preferences among respondents, but also because it is a characteristic that water managers and policymakers can influence via education and outreach programs. Descriptive analysis of water knowledge levels will determine whether water knowledge differences exist among western households. Including water knowledge as an explanatory variable in Equation 24 will indicate whether differences in water knowledge contribute to observed heterogeneity in WTP, and will provide insight into the likely payoff of investing in a water education program.

In this context, measuring respondents' water knowledge becomes an important task; yet there is no standard measure of water knowledge. In the present analysis, water knowledge is measured by respondents' stated level of familiarity with the following fourteen water terms: *groundwater, surface water, conjunctive use, water reuse, consumptive use, beneficial use, return flows, prior appropriation, riparian right, evapotranspiration, interstate compact, water decree, diversion*, and *river call.* While perceptions of knowledge may not always be a reliable indicator of actual knowledge, other studies have utilized self-reported measures of knowledge (for example, Arcury et al., 1985). The reliability of the water knowledge questions—which refers to the consistency with which respondents answer them—was confirmed by responses to another knowledge-based question that appeared later in the questionnaire.

For each water term, responses of *not at all familiar* were assigned a value of one, while responses of *somewhat familiar* and *very familiar* were assigned values of two and three, respectively. Respondents were then given a composite water knowledge score by summing their scores for each water term for a maximum possible score of 42. The composite water knowledge score is thus an ordered discrete variable. A respondent's familiarity with water terminology may indicate interest in water use and policy and greater awareness of water issues facing the west, and is expected to have a positive effect on WTP.

Explanatory Variables: Preference Rankings

An individual's values and beliefs impact his or her behavior (Espeland, 1998, p. 232; Bright and Burtz, 2006) and can be expected to influence the WTP decision. With this in mind, respondents were asked their preferences for addressing long- and short-term water scarcity. Responses to several of these questions served as explanatory variables in the logit model. In one such question, respondents were asked to rank the following funding options for acquiring water for long term needs:

1. Increase rates on all water bills.
2. Increase water rates for households that use more water.
3. Increase fees on new homes and new housing developments.
4. Increase water rates for new housing developments.
5. Issue city or municipal district bonds.
6. Reallocate funds from other parts of the city budget to pay for water.
7. Obtain subsidies from the federal government.

The dummy variable *New Housing* indentifies households whose top-ranked funding option was either to increase fees on new homes and housing developments or to increase water rates for new housing developments. Households who feel that long-term water acquisition should be funded via fees on new housing developments may view growth as the primary source of the problem, and may be less willing to volunteer monetary support for programs that address water scarcity; this variable is thus expected to be negatively correlated with WTP. The dummy variable *Federal Subsidies* indentifies households whose top-ranked funding option was to obtain federal subsidies. Such a choice implies a belief that the federal government should bear the responsibility of paying for water programs, which will tend to spread the cost over a larger tax base; it is thus expected to be negatively correlated with WTP.

Explanatory Variables: Likert Scale Rankings

Another set of attitudinal questions were posed using a 5-point Likert scale, whereby the extent of agreement with a statement is indicated by selection of one of five responses: *strongly disagree, disagree, neither agree nor disagree, agree,* or *strongly agree.* If a respondent strongly agreed with the statement, the response was given a value of 5, whereas *agreed, neutral, disagreed,* and *strongly disagreed* responses were given values of 4, 3, 2, and 1, respectively. Variables based on the Likert scale include:

Conservation Concerned: This variable indicates the level of agreement with the statement "Water conservation is an issue I am personally concerned about." Individuals concerned about an issue generally have greater motivation to do something about it—such as pay a fee. Individuals who agree with this statement may be more willing to pay the fee for those options aimed at conserving and reusing water and setting aside water for non-consumptive uses.

Public Money: This variable indicates the level of agreement with the statement "Public money should be used to develop or acquire new water resources." Agreement with this notion suggests that the respondent may be aware of the public good characteristics of water resources and may be more likely to pay the fee.

Voluntary Restrictions: This variable indicates the level of agreement with the statement "Household water restrictions should be voluntary rather than mandated by the government." Individuals who believe strongly in independent choice and self-responsibility may be less likely to pay a fee in support of any program that is administered by a government entity; thus, this variable is expected to have a negative effect on WTP.

Enough Water in the West: This variable indicates the level of agreement with the statement "There is enough water in the western U.S. to meet the future needs of all the people and businesses in the west for the next 25 years." Individuals who agree with this statement can be expected to have a lower willingness to pay for water programs.

Policymakers Understand: This variable indicates the level of agreement with the statement, "Water policymakers understand my priorities for water use." Individuals who agree with this statement may have greater trust in public officials to allocate fee revenues wisely, and thus may be more willing pay a fee.

Current Management: This variable indicates the level of agreement with the statement "I am satisfied with the current system of water management." Those who are satisfied with current water management practices may be less likely to pay money for a new program.

Limit Growth: This variable indicates the level of agreement with the statement, "Growth of cities should be limited to manage water scarcity." Agreement with this statement may indicate a feeling that more recent residents are to blame for current water woes and that they alone should pay for any new water resources. While this variable is similar to *New Housing* and is expected to have similar effects, the *New Housing* variable allows for households who do not want to limit growth but want growth to pay for itself. Agreement with this statement is thus expected to have a negative effect on WTP.

Regional Planning Needed: This variable indicates the level of agreement with the statement "Regional land use and water planning is needed to manage water scarcity." Respondents who believe that regional land and water planning is needed may recognize the spatial dimension of water resources management and urban growth and may be less satisfied with current local planning, and may thus be more likely to pay the proposed fee.

Do Nothing: This variable indicates the level of agreement with the notion that cities should not be required to do anything to compensate rural communities after a rural-to-urban water transfer. Respondents who agree with this notion may not consider the public good aspects of water transactions and may thus be less willing to pay the fee.

Economy over Environment: This variable indicates the level of agreement with the statement "In water planning, the health of the economy is more important than protecting the environment." Empirical evidence indicates that environmental concern is a major factor in consumer decision-making (Kilbourne and Beckman, 1998; Diamantopoulos et al., 2003; Barber et al., 2009). Agreement with this statement is indicative of relative preference for economic development over environmental conservation, and may influence the decision to pay the fee, given the various programs the fee aims to support.

Explanatory Variables: Demographic Characteristics

In addition to traditional demographic variables of age, gender, ethnicity, and income, the following demographic variables were included:

Homeowner: This dummy variable indicates a respondent who owns his or her place of residence. An individual's type of residence might influence their perceptions of water use and their preferences for addressing scarcity. For instance, because they are more likely to have lawns, homeowners may face a higher water bill to begin with and may thus be more sensitive to increasing fees. Some apartment-dwellers do not even pay a separate water bill, instead paying a flat fee that is included as a part of their overall rent payment. Because these renters would not have to bear the burden of a water fee, at least in the short term, they would be expected be more supportive of such a fee.

College: This dummy variable indicates that a respondent has attended some college. It is included to control for any influence that higher education may have on WTP.

Years in the West: Individuals with a longer tenure in the west may have a greater awareness of western water issues and may be more sensitive to the recent population influx. Their opinions may thus differ from those who arrived in the west more recently.

City: This dummy variable indicates that a respondent live in a city with a population of 100,000 or more. City-dwellers may have different levels of concern for irrigated agriculture and rural communities than individuals who live in smaller communities.

Water Restriction: This dummy variable indicates that a respondent's city implemented a mandatory water restriction within the past year. Such a restriction would likely increase awareness of water scarcity and may influence opinions regarding water policy.

State Dummies: A respondents' home state may influence his or her experiences with and attitudes toward various water management practices.

Final Set of Explanatory Variables

A model with too many variables can have poor predictive accuracy and can be difficult to interpret (Lobell et al., 2007). In pursuit of a more parsimonious model, some researchers omit variables that are not individually statistically significant (e.g., Loomis et al., 2009). The validity of such an omission can be tested by restricting the coefficients on the individually insignificant variables to equal zero. A χ^2 statistic then measures how close the unrestricted estimates come to satisfying the restrictions under the null hypothesis. This test—the results of which are displayed in Table 21—was used to reduce the logit model to a more a more parsimonious model. Although the dummy variable for gender was not statistically significant, gender has been found in previous studies to have a statistically significant effect on WTP[13] and was thus retained in the final model. The final set of explanatory variables is displayed in Table 22. Correlation coefficients among the explanatory variables are displayed in Tables B1 and B2 in Appendix B.

Table 21: A Test for Redundant Variables

Redundant Variables	**Test Results**
Years in West, Water Restriction, College, State Dummies	χ^2 (19) = 22.08 (Prob = 0.2802)

[13] For example, Breffle et al. (1999), DuPont (2000), and Dong et al. (2004) all find WTP to be higher among males.

Table 22: Explanatory Variables and Expected Sign

Explanatory Variables	Expected Direction of Impact on WTP
Water Knowledge (discrete ordered variable)	Positive
Proposed Fee Amount	Negative
Perceptions and Preferences	
Conservation Concerned (Likert variable)	Positive
Public Money (Likert variable)	Positive
Voluntary Restrictions (Likert variable)	Negative
Enough Water in the West (Likert variable)	Negative
Policymakers Understand (Likert variable)	Positive
Current Management (Likert variable)	Negative
Limit Growth (Likert variable)	Negative
New Housing (ranking dummy variable)	Negative
Regional Planning Needed (Likert variable)	Positive
Federal Subsidies (ranking dummy variable)	Negative
Do Nothing (Likert variable)	Negative
Economy over Environment (Likert variable)	Unknown
Demographics	
Male (dummy variable)	Positive
Income (discrete ordered variable)	Positive
Homeowner (dummy variable)	Negative
Age (discrete ordered variable)	Negative
Caucasian (dummy variable)	Unknown
City (dummy variable)	Unknown

Model Fit

Statistical significance of individual explanatory variables in the logit model is interpreted in the usual way; the *z*-statistic in ML estimation is equivalent to the *t*-statistic in OLS estimation, although the normal distribution table, rather than the student's *t* distribution table, is used in hypothesis testing.

One measure of overall model fit is the McFadden-R^2, which is calculated as follows:

$$\text{McFadden-}R^2 = 1 - (L/L') \qquad (30)$$

where L is the maximized value of the log-likelihood function and L' is the maximized value of the log-likelihood function when all coefficients except the constant term are restricted to zero. McFadden-R^2 values will always fall between zero and one, and can be used as a criterion for comparing models, with larger values generally desired. However, as in the case of traditional R^2 measures, the McFadden-R^2 value for a single model has little meaning in and of itself.

The Hosmer-Lemeshow (H-L) statistic is a measure of lack of fit. The procedure involves grouping of the observations based on the expected probabilities and then comparing the fitted expected values to the actual values to test the hypothesis that the difference between observed and expected events is simultaneously zero for all the groups. Thus, small values of the H-L statistic (and large p-values) indicate good model fit. The distribution of the H-L statistic ha the statistic is well approximated by a χ^2 distribution.

Goodness-of-fit can also be evaluated by the percentage of correctly-predicted responses. First, a discrete classification is performed using the predicted probability *p-hat* = 1 – $F(-x'\beta)$, with observations classified according to having predicted probabilities that are above or below 0.5. Next, observations are classified using the predicted probability *p-hat* given by the sample proportion of "yes" observations. This probability, which is constant across individuals, is the value computed from estimating a model that includes only the intercept term. Correct classifications are obtained when either the predicted probability is less than or equal to 0.5 and the observed response is "no", or when the predicted probability is greater than 0.5 and the observed response is "yes". While there is no specific requirement for the minimum number of correct predictions (Hanemann and Kanninen, 1999), higher proportions of correctly-predicted responses are desired.

The Fee Allocation Decision

Stakeholders are interested not only in the overall support that western households have for funding water development initiatives but also in the implicit ranking that individuals have for different types of initiatives; for instance, whether western households tend to support water storage projects more than conservation initiatives. Using rational choice theory, any value or preference can be made commensurate to any other, and any choice can be transformed into a quantitative relationship by placing the value of one alternative in terms of the other. Thus, value is revealed in comparison between alternatives—in the trade-offs that are made among them (Espeland, 1998, p. 24; Freeman, 2003, p. 162).

The support for each particular type of water initiative was considered when respondents were asked to allocate the fee among the eight initiatives in any way they wished, *even if they did not support the fee.* Respondents' preferred allocation of the fee across the eight water initiatives provides insight into the utility individuals expect to receive from each initiative relative to the others. It should be noted that because there is no alternative numeraire good under consideration, such comparisons reveal trade-offs among the proposed initiatives only; the programs' values relative to other goods are not revealed.

Results and Discussion

This section begins with a discussion of the results of the estimation of Equation 24. The median WTP of survey respondents is then calculated according to Equation 25. The results of the fee allocation question are then displayed and discussed. Respondents' self-reported water knowledge is then discussed and the marginal effect of water knowledge on WTP is calculated. Finally, the results of the separate logit regressions based on water knowledge level are discussed. Respondents' demographic, attitudinal, and preference characteristics are displayed and discussed in Appendix B.

Willingness to Pay a Water Fee

Using the DC format, respondents were asked if they would be willing to pay a fee on their water bill during the summer months if the revenue was divided among eight listed programs. Just over half (52.1 percent) of all respondents stated a willingness to pay the fee. In line with expectations, the proportion of respondents willing to pay the fee fell as the proposed fee amount rose (Table 23).

Table 23: Willingness to Pay a Water Fee during the Summer Months

Proposed Fee	$5	$10	$15	$20	$25	Overall
YES Responses	63.6 %	55.5 %	47.3 %	43.5 %	37.3 %	52.1 %

What else drives the decision to pay the water fee? Insight is provided via estimation of the parameters in Equation 24, the results of which are displayed in Table 24. The marginal effect of the proposed fee amount on the WTP decision (calculated according to Equation 26) and the marginal effect of the other explanatory variables on median WTP (calculated according to Equation 27) are displayed in the last column of the table. These estimates can inform water managers about which demographic and attitudinal characteristics are particularly important to households' support of the fee.

Table 24: Binary Logit Analysis of Western Households' Willingness to Pay a Water Fee

Dependent Variable: Dichotomous WTP Response			
Variable	Coefficient	Probability	Marginal Effect
C	0.1337	0.7710	--
Fee**	-0.0739	0.0000	-31%
Enough Water in the West**	-0.0938	0.0040	-$1.27
Conservation Concerned**	0.1798	0.0000	$2.43
Voluntary Restrictions**	-0.1936	0.0000	-$2.62
Regional Planning Needed**	0.3036	0.0000	$4.11
Limit City Growth	-0.0493	0.1320	-$0.67
Public Money**	0.3290	0.0000	$4.45
Current Management**	-0.0948	0.0210	-$1.28
Policymakers Understand**	0.1644	0.0000	$2.22
Do Nothing**	-0.1812	0.0000	-$2.45
Federal Subsidies**	-0.4951	0.0000	-$6.70
New Housing**	-0.2576	0.0010	-$3.48
Economy over Environment**	-0.1223	0.0000	-$1.66
Water Knowledge**	0.0124	0.0250	$0.17
Caucasian**	0.3818	0.0000	$5.16
Age**	-0.0723	0.0000	-$0.98
Age^2**	0.0007	0.0000	$0.01
Income**	0.2322	0.0000	$3.14
Homeowner**	-0.5013	0.0000	-$6.78
City**	0.1261	0.0490	$1.71
Male	-0.0040	0.9570	-$0.05
Correct classifications: 68.5%		Pseudo Log-likelihood: -3046	
H-L statistic: 9.43 (probability = 0.3077)		McFadden R-squared: 0.1359	

**Statistically significant, $\rho<0.05$

Consistent with Table 23, the size of the proposed fee was found to have a statistically significant negative effect on the decision to pay the fee. As estimated by Equation 26, the marginal effect of the fee amount on the WTP decision is -0.31, indicating that a one-dollar increase in the proposed fee reduces the probability of a "yes" response by 31 percent.

In the west, a perception exists that in-migrating populations are increasing the demand for water resources, which is reflected by the findings here. Nearly a quarter of respondents listed either "Increase fees on new homes and new housing developments" or "Increase water rates for new housing developments" as their first choice for funding new water supplies. These preferences are operationalized together as the variable *New Housing*, which was found to have a relatively large negative marginal effect on WTP. Furthermore, agreement that there is enough water in the west (as described by the variable *Enough Water in the West*) was also found to have a relatively large negative marginal effect on WTP. Although there little correlation was found between tenure in the west and awareness of water scarcity, if newer residents to the west are *perceived* as having a diminished sense of water scarcity, this could further perpetuate the general view that newer residents to the west should bear a greater portion of the burden of securing water supplies for the future.

As hypothesized, homeowners were less likely to give a "yes" response to the WTP question. This is likely due in large part to the fact that homeowners are more likely than renters to have a lawn and thus face a higher water bill to begin with—and may thus be more sensitive to increasing fees. However, because some renters do not pay a separate water bill, they may not have to bear the burden of a water fee, at least in the short term. Thus, it may not be that renters are more supportive of the fee so much as they are less likely to have to pay the fee and are thus less opposed to it.

Those who feel that the growth of cities should be limited (as described by the variable *Limit City Growth*) were also less likely to pay the fee, as were those who believe there is enough water in the west, those who believe that water restrictions should be voluntary, those who feel that water acquisition should be paid with government subsidies, and those who think the economy should be given precedence over the environment—all as expected. Up to a certain age, age has a negative effect on willingness to pay (as hypothesized). However, beyond a certain age, further increases in age actually have a positive effect on willingness to pay. This finding is in line with Deller et al. (1997)—who found that younger individuals and retirees are more likely to support economic development efforts—and may be due in part to older individuals having higher discretionary income.

Respondents' income level was found to have a positive influence on the WTP decision, suggesting that this bundle of water initiatives is a normal good. Income has a relatively large marginal effect, perhaps suggesting that higher income households can share a larger burden of supporting water initiatives, a revenue-generating model that is consistent with property tax collection to support public utility efforts (if higher incomes are consistent with higher property valuation) and progressively-tiered water rates (if higher water use is positively correlated with income).

As expected, respondents who are personally concerned about water conservation (as described by the variable *Conservation Concerned*) were more likely to be willing to pay the fee, as were those who believe that public money should be used for water acquisition (*Public Money*), that policymakers understand the public's priorities (*Policymakers Understand*), and that regional planning is needed (*Regional Planning Needed*). Caucasians and city-dwellers were also more likely to pay the fee. Water knowledge was also found to increase the probability that a respondent was willing to pay the fee. As one of the few factors that water managers can influence directly, the relationship between water knowledge and WTP is analyzed and discussed in greater detail in a following section.

The variable *Voluntary Restrictions* was found to have a large negative effect on WTP, while *Regional Planning* was found to have a large positive effect on WTP. These opposing effects may relate to differing views as to who is affected by and responsible for water issues. Households who feel that water restrictions should be voluntary rather than mandated by the government may not see water scarcity as a problem that will affect them, or if it does affect them, that they should be able to address the problem as they see fit and only to an extent that is agreeable to them. In contrast, households who feel that regional planning is needed to address water scarcity likely recognize that water scarcity is an issue that will affect everyone and that the best solutions will likely need to involve entire communities.

<u>Median WTP</u>

Because the water supply fee has been posed as a dichotomous choice question, the researcher is unable to infer the true WTP of an individual who responds yes or no. However, given the choices made by individuals at various proposed fee amounts, while controlling for heterogeneity in the explanatory variables among the respondent population, an estimate of median WTP for the sample can be obtained. Using the coefficient estimates in Table 25 to solve Equation 25, the median WTP amount is estimated to be $15.65 per summer month, or $46.95 per year. Using the Krinsky-Robb bootstrap technique as outlined in Loomis et al. (1991), a 95 percent confidence interval around the median WTP estimate was constructed, revealing a lower bound of $14.81 and an upper bound of $16.93.

While there is no directly comparable study, these WTP estimates are similar to estimates of households' WTP for water supply reliability. Howe and Smith (1994) used contingent valuation survey methods to measure what residents in three Colorado cities would be willing to pay for different levels of water supply reliability. Mean WTP ranged from $17.68 to $35.91 per year (in $2008), depending on the change in water supply reliability. In a similar study of residents in seven Texas cities, Griffin and Mjelde (2000) estimated mean WTP to be $131.35 per year (in $2008). Using a two-stage linear programming approach, Alcubilla and

Lund (2006) found that for any given retail price of water, customers are willing to pay between $178 and $1,011 per year (in $2008) to decrease the probability of a water shortage.

<u>*Water Knowledge*</u>

One of the research objectives was to determine whether water knowledge has an influence on the willingness to pay for various water initiatives. It was shown in the previous section that an individual's water knowledge—measured by their self-reported familiarity with water terminology—has a positive and statistically significant influence on their willingness to pay a fee for the water initiatives described previously. In light of this finding, it is important to gauge western households' current familiarity with water terminology and to examine in more detail the influence that this familiarity has on WTP.

The questionnaire gauged water knowledge in two different ways: perceptions of the water used by different entities and self-reported familiarity with water terminology. Because the first of these was not used in the regression analysis, it is discussed in Appendix B. The second measure of water knowledge comprises the *Water Knowledge* explanatory variable. To construct this measure, respondents were asked to indicate on a three-point scale their level of familiarity with fourteen water terms. Table 25 displays the percentage of respondents indicating each level of familiarity with each term. None of the terms was *very familiar* to a majority of respondents. Respondents were least familiar with "river call" and "conjunctive use". The term "riparian right" was also unfamiliar to most respondents, which can be expected given that riparian water rights are not common in the west. Surprisingly, "interstate compact" had fairly low familiarity in spite of recent media coverage of the interstate compact dividing water in the Colorado River Basin and recent litigation between Colorado and downstream states in the Republican, Platte, Rio Grande, and Arkansas river basins.

Table 25: Respondents' Stated Familiarity with Water Terminology

	Very Familiar (%)	Somewhat Familiar (%)	Not at All Familiar (%)
Ground Water	47.4	42.4	10.2
Surface Water	38.2	43.2	18.6
Water Reuse	24.5	48.1	27.4
Diversion	23.7	44.1	32.2
Consumptive Use	23.9	42.9	33.2
Beneficial Use	15.3	39.6	45.1
Return Flows	11.8	32.1	56.1
Prior Appropriation	9.9	25.3	64.7
Evapotranspiration	10.3	22.5	67.2
Interstate Compact	8.7	24.3	67.0
Water Decree	7.2	23.3	69.5
Riparian Right	7.3	18.2	74.5
Conjunctive Use	5.1	18.4	76.5
River Call	5.0	18.9	76.1

Overall, respondents report little familiarity with water terms. Respondents were most familiar with the terms "ground water" and "surface water", but 10 and 19 percent of respondents, respectively, had very little background with each of these common water resources terms. On the other hand, at least 15 percent of respondents were very familiar with more technical terms like 'beneficial use'. Thus, it appears as though familiarity with these terms is fairly heterogeneous, where a small proportion of individuals with little water knowledge and sophisticated water knowledge, respectively, and the mass of respondents lie in between these extremes. Indeed, a histogram of respondents' composite water knowledge scores takes a (somewhat left-skewed) bell shape (Figure 4). The mean score was 23, while the median was 22 and the mode was 19. Fifty-eight respondents reported the maximum score of 42, indicating high familiarity with all of the terms.

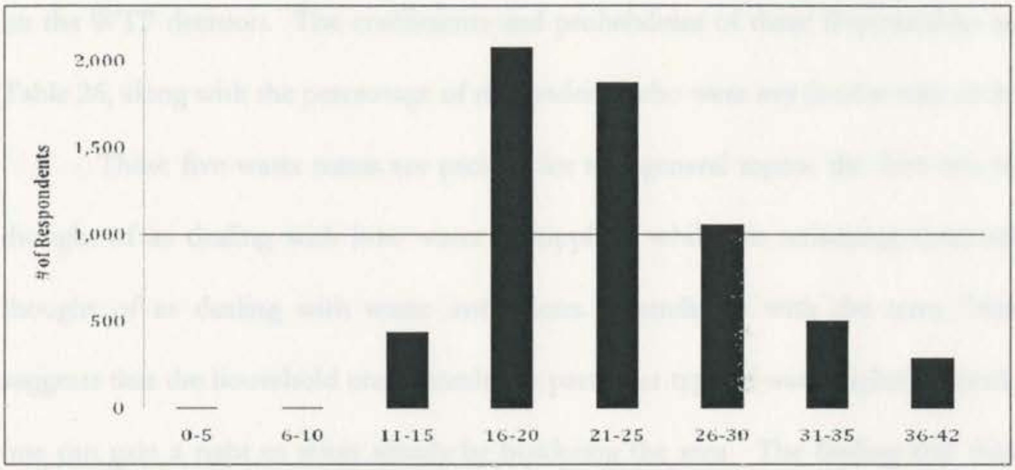

Figure 4: Histogram of Respondents' Composite Scores for Self-Reported Water Knowledge

The previous discussion illustrated that respondents report relatively low familiarity with water terms and that levels of familiarity vary across individuals. Furthermore, it has been shown that water knowledge has a statistically significant positive effect on the decision to pay a water fee. But is the effect substantial enough to offset the costs of a water education effort? Although the marginal effect of water knowledge is small relative to the other variables analyzed here, the variable nonetheless has a non-negligible effect on the WTP amount: increasing the composite water knowledge score by just one point increases WTP by $0.17 per summer month. Maximum familiarity with all fourteen water terms results in a WTP of $18.81, an increase of $3.16.

Additional insight can be gained by quantifying the relationship between familiarity with particular water terms and the WTP decision. To this end, the logit model was re-run with the familiarity scores for each individual water term in place of the composite water knowledge score. While none of the fourteen water terms had a negative influence on the WTP decision, just five of the terms were found to have a statistically significant positive effect on the WTP decision. The coefficients and probabilities of these five variables are shown in Table 26, along with the percentage of respondents who were *very familiar* with each of them.

These five water terms are proxies for two general topics: the first two terms can be thought of as dealing with how water is supplied, while the remaining three terms can be thought of as dealing with water institutions. Familiarity with the term "riparian right" suggests that the household understands the particular type of water rights institution in which one can gain a right to water simply by bordering the area. The finding that familiarity with this term increases the likelihood that a respondent will be willing to pay the fee, combined with the finding that this term is only familiar to a minority of respondents, suggests that it may be a worthwhile topic to include in a water education program. Those who are knowledgeable about the riparian rights may also be knowledgeable about other types of institutions (e.g., right-to-capture, prior appropriation), suggesting a very sophisticated knowledge of water institutions. Thus, an educational program focused on institutions may prove to be even more beneficial than one focused specifically on riparian rights.

Table 26: Individual Water Terms that Influence the WTP Decision

Water Term	Coefficient	Probability	Very Familiar
Surface Water	0.085	0.0902	38.2 %
Diversion	0.135	0.004	23.7 %
Prior Appropriation	0.100	0.0653	9.9 %
Interstate Compact	0.141	0.0126	8.7 %
Riparian Right	0.161	0.0091	7.3 %

Additional insight can be gained by uncovering the differences in WTP among groups of varying levels of water knowledge. Thus, the WTP of respondents whose water knowledge score was below the sample median was compared with the WTP of respondents whose water knowledge score was at or above the sample median. A comparison of the two regressions is displayed in Table 27. The logit model was found to predict the WTP decision equally well for those with lower water knowledge scores and those with higher water knowledge scores. Median WTP for the low water knowledge group was estimated to be $10.71, while median WTP for the high water knowledge group was estimated to be $23.50. It is interesting to note that when an individual has relatively high water knowledge, being Caucasian or living in a city no longer influences WTP.

Table 27: Logit Analysis of WTP according to Water Knowledge

Explanatory Variable	Low Water Knowledge	High Water Knowledge
Constant	0.0132	0.2441
Fee	-0.0677**	-0.0692**
Enough Water in the West	-0.0588	0.1757*
Conservation Concerned	0.1966**	0.1669**
Voluntary Restriction	-0.1885**	-0.1900**
Regional Planning Needed	0 2366**	0.3679**
Limit City Growth	-0.1243*	-0.0006
Public Money	0.3903**	0.2641**
Current Management	-0.2409**	-0.0068
Policymakers Understand	0.3104**	0.0309
Do Nothing	-0.2502**	-0.1475**
Federal Subsidies	-0.3724**	-0.5528**
New Housing	-0.0889	-0.3775**
Economy over Environment	-0.0585	-0.1724**
Caucasian	0.5254**	0.2088
Age	-0.0764**	-0.0603**
Age2	0.0008**	0.0006**
Income	0.2573**	0.1877**
Homeowner	-0.4296**	-0.5104**
City	0.2761**	0.0427
Male	-0.0413	-0.0031
Pseudo Log-Likelihood	-1465	-1840
McFadden R^2	0.1283	0.1232

**Statistically significant at the 5% level
*Statistically significant at the 10% level

Fee Allocation

One of the primary purposes of this study is to uncover households' willingness to pay for long and short term water initiatives according to Equation 25. However, calculating the median WTP does not reveal how respondents prefer to divide the fee among the eight programs; rather, it measures support for all eight programs without regard to allocation. An assessment of western households' preferred allocation of the fee can provide additional information to water stakeholders that might assist in prioritizing among alternatives, water initiatives and education programs.

The fee allocation decision can be thought of as a "vote" the respondent makes for one alternative relative to another, with a higher allocation for an initiative indicating that it is more heavily supported by the respondent. The average allocations (Table 28) are generally consistent with respondents' preferences for long-term water supply strategies (Figure B7).

Table 28: Average Fee Allocation among Eight Water Program

Program	Average Allocation
Construct a reservoir for storage	17.2%
Keep irrigated farms in production	16.2%
Create a system to reuse household water for public landscapes	16.2%
Implement programs to reduce household water consumption	13.9%
Set aside water for wildlife habitat in nearby streams	12.1%
Provide subsidies for water-efficient appliances	10.9%
Make infrastructure improvements in rural communities	6.9%
Set aside water for public based recreation	6.6%

It is striking that, while much of the water policy literature for some time has emphasized the need for demand management (as opposed to supply augmentation) and the likely need for the reallocation of some water from existing uses (e.g., Young 1986; Gleick 2000), respondents prefer to allocate the largest proportions of the fee toward reservoir construction and keeping irrigated farms in production. It may be that these two activities are perceived as benefitting a greater portion of the population. The stated support for keeping irrigated farms in production is in line with previous findings that westerners are increasingly in favor of regulations that aim to retain water within a watershed for the benefit of local societies (Tarlock 1991; Specter 2006). It is encouraging that programs designed to reuse household water received an equal proportion of the fee as those designed to keep irrigated agriculture in production. Programs designed to reduce household water consumption, set aside water for wildlife, and provide subsidies for water-efficient appliances all received more than ten percent of the fee.

Average allocations represent just one of many ways to describe respondents' preferences for allocating the proposed water fee. Additional insight can be provided by determining the number of respondents that allocated *any* amount toward a particular program, the number of respondents that allocated the *majority* of the fee toward the program, and the number of respondents that allocated *100 percent* of the fee toward the program. These data are displayed in Figure 3, and while largely in agreement with the average allocations, there are a few exceptions. For example, more respondents allocated a proportion of the fee toward reusing household water and keeping irrigated farms in production than toward reservoir construction, even though the average allocation reported for reservoirs is among the highest. One striking result is that subsidies for water-efficient appliances received a larger number of full allocations when compared to other program options. Thus, while *on average* subsidizing water-efficient appliances is not highly preferred, those who do prefer this program tend to do so strongly, allocating relatively large proportions of the fee toward it.

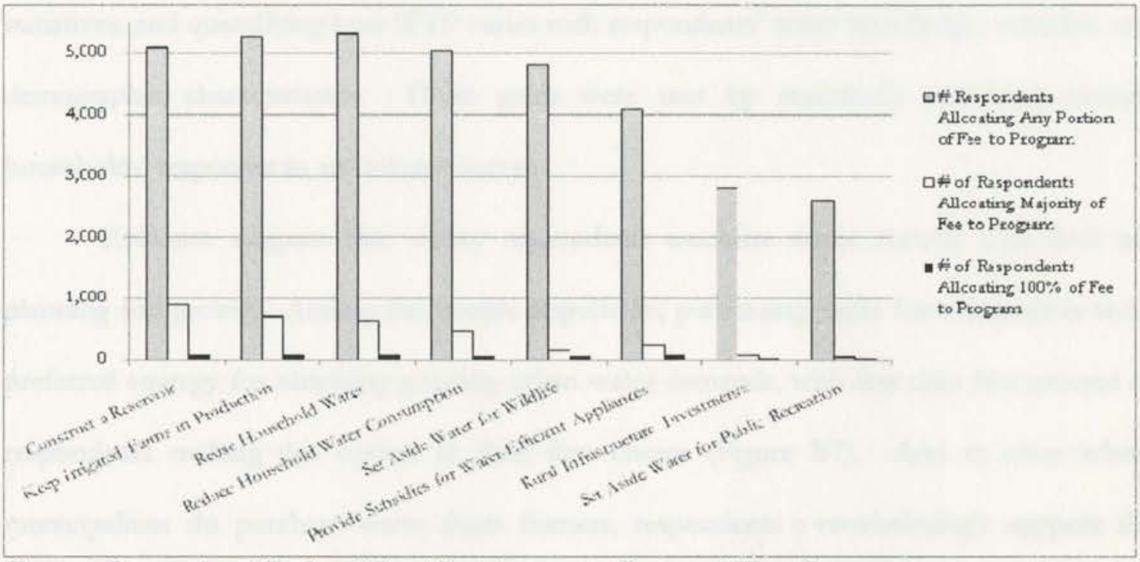

Figure 3: Respondents' Preferred Fee Allocation among Proposed Water Programs

Those respondents who allocated the fee entirely to one program may have different demographic characteristics and attitudes about water management in the west, which may translate into a different WTP the fee. On one hand, allocating 100 percent toward one program indicates a certain level of passion about that particular program, which may translate into higher WTP. On the other hand, because the dichotomous WTP question suggested that the fee would be split among all eight programs, these respondents may be less likely to pay the fee since they prefer the fee be allocated to just one program. To investigate this matter, the means from just these individuals were input into Equation 25. This resulted in an estimated median WTP of $10.40—34 percent lower than the median WTP of all respondents.

Conclusions

The primary goals of this study were to provide stakeholders with insights into western households' preferences for meeting water resource needs and their familiarity with water resources and terminology; estimating western households' willingness to pay for eight water initiatives; and quantifying how WTP varies with respondents' water knowledge, attitudes, and demographic characteristics. These goals were met by statistically analyzing western households' responses to an Internet survey.

Evidence suggests that survey respondents associate water scarcity with land use planning and growth. Among the sample population, purchasing water from farmers is not a preferred strategy for satisfying growing urban water demands, with less than five percent of respondents ranking this option as their first choice (Figure B7). And in cases where municipalities do purchase water from farmers, respondents o verwhelmingly support the compensation of rural communities from which the water is transferred, with a number of forms of compensation deemed acceptable (Table B7). Importantly, the support for irrigated farms and rural communities is not confined to those who work on farms or live in rural communities—less than three percent of survey respondents were employed in farming or ranching, and only a quarter of respondents lived in towns with less than 10,000 residents. In general, survey respondents are dissatisfied with the approach that water suppliers are currently using to manage water resources (Table B8) and are willing to pay for a number of water conservation and reallocation programs, particularly those aimed at reservoir construction, keeping irrigated farms in production, and reusing household water (Table 27).

While western households appear to be generally aware of looming water scarcity in the west (Figures B12 and B13), there is opportunity to increase knowledge about water allocation (Figure B10 and B11). Water knowledge and attitudes about policymakers were each found to have an impact on WTP, suggesting that community education and outreach may directly influence financing. Familiarity with the following five terms were found to be especially important to the WTP decision: surface water, diversion, prior appropriation, riparian right, and interstate compact. Because these terms are very familiar to only a minority of respondents, an educational program addressing these topics may be a particularly worthwhile investment.

Another policy-relevant variable that was found to increase WTP among the sample population was the perception that policymakers understand the public's water use priorities. Thus, any campaign to implement a water fee would likely benefit from a community outreach component. If the proposed water fee is voluntary, it may prove fruitful to target relatively young and wealthy city-dwellers, as these groups were more likely to be willing to pay the fee. The programs preferred most by respondents were those aimed at constructing a reservoir, keeping irrigated farms in production, and creating a system to reuse household water for public landscapes.

A number of limitations of the research are noted. The findings reported here may not be representative of all western residents if respondents differ systematically from non-respondents. The e-mail invitations did not reveal the subject of the questionnaire—only when the link to the questionnaire was opened was the topic revealed—thus minimizing any non-response bias from having a large number of respondents who are engaged in water matters. To test for attitudinal bias, an e-mail containing a small subset of the original survey questions was sent to non-respondents[14]. The results did not reveal any systematic differences between members of sample who completed the questionnaire and those who did not. However, as can be seen in Table B3, respondents differed somewhat from the typical western

[14] Non-respondents were asked the extent to which they agreed or disagreed with the following statements:
1. Water conservation is an issue I am personally concerned about.
2. I participate in water conservation strategies in my daily life.
3. In water planning, the needs of the natural environment deserve the same consideration as the economy.

resident in terms of some demographic characteristics, and thus may not be fully representative of the average western resident.

Many contingent surveys suffer from a high percentage of respondents who express a WTP equal to zero for the provision of the good or service in question. Debriefing questions can be used to discriminate between true zero values and protest responses (Haab 1999), with the standard approach being to remove protest responses from the analysis. However, such a selective data removal will affect the validity inferences made from of estimates obtained from a given sample if the group of protesters is significantly different from the rest of the respondents (Halstead et al. 1992; Shyamsundar and Kramer 1996; Jorgensen and Syme 2000). The present analysis did not attempt to remove protest responses from the analysis.

The literature to date is mixed on the most appropriate model of the household. While there is evidence that, at least for some goods, there can be significant differences in the values elicited from the household as a whole and from its various components (for example, Lundberg et al., 1997; Browning and Chiappori, 1998; Phipps and Burton, 1998; Bateman and Munro, 2003, 2005, 2009), it remains unclear whether the individual or household provides the most accurate estimate of household behavior (Bateman and Munro, 2009). McFadden (1994) found evidence that respondents do not aggregate linearly over household members and that they usually impute a WTP to other household members lower than their own. However, to the extent that household heads are likely more familiar with the households' water usage and payments, they are likely to be more connected to the WTP decision and more likely to give a meaningful response. This survey did not specifically target household heads; rather the pool of potential respondents was made up of individuals—who may or may not be the head of their household—who had signed up in advance to participate in surveys.

Respondents' stated WTP values will likely depend on the amount of information they are given about a given program. For instance, it is possible that the relatively large allocation toward reservoir construction was influenced by the relatively high cost of reservoir construction. Although the WTP question did not clearly specify the nature of the good that respondents were being asked to pay for, the intent of this study was to gauge the support for different *types* of programs rather than for any *specific* program, using WTP as a proxy for preferences rather than as a quantitative measure for benefit-cost analysis. The format of the WTP question allowed the relative values of different types of water initiatives to be assessed without asking multiple WTP questions. As these types of programs are implemented, it will be useful to assess how preferences and WTP change according to specific details of the programs.

Because some of the programs considered have both public and private aspects, an individual's WTP may stem from a combination of the personal benefit they expect to receive if the program is instated, as well as the "warm glow" they would receive by supporting the program. While strategies exist to separate the two components of WTP, such separation is not necessary if the intent is not to identify the source of WTP but rather the WTP amount. As noted by Nunes and Schokkaert (2003), the modern theory of social choice has long emphasized that it is immaterial whether individual's preferences reflect selfish interest or moral judgment.

CHAPTER 4: LEASING AGRICULTURAL WATER IN COLORADO'S SOUTH PLATTE BASIN

Problem Statement

According to the State Demographer, Colorado's population is forecast to increase approximately 60% by 2035 and 100% by 2050, with the majority of the growth expected to occur in the South Platte Basin. In addition to the increases in water demand associated with population growth, there is additional pressure from expanding recreational and environmental interests, interstate compacts, and changing well augmentation rules. Yet most rivers in Colorado are already fully appropriated, and groundwater stores are declining due to widespread drought and rising temperatures (Brunswig, 2006). As a result, a water gap is expected to develop within the next five years and increase thereafter.

Understandably, state and regional planning bodies, researchers, and the public are very concerned about the adequacy of available water supplies to sustain Colorado's population and economic growth. Cities have sought to acquire water from farmers whose water rights tend to have higher priority in the prior appropriations system and whose uses garner lower marginal economic value than those of municipal and industrial (M&I) uses (Nichols, 2004; Knapp et al., 2003). Permanent water transfers have been the historical approach and are expected to play a continued role in meeting cities' stated shortfalls (Doherty, 2010). However, despite typically providing net benefits to statewide economies (Griffin and Boadu, 1993), permanent water transfers can threaten the economic viability of agricultural producers, the businesses that support them, and the communities in which they reside—particularly if other forms of economic activity are not developed to replace that which is lost from agriculture.

While appropriative water law protects the rights of other appropriators when water is transferred, other third parties are not typically protected from the effects of transfers (Sax, 1995; Gomez and Loh, 1996). Similarly, while farmers are compensated when their water rights are sold, compensation is not typically made for the third-party c osts o f reduced agricultural production, such as lost tax revenues (Colby, 1990; Zilberman and Schoengold, 2005). When third-party costs are ignored, the marginal cost of a water transfer appears artificially low, resulting in a lower market price for the water and a higher quantity of water transferred than would be socially optimal.

While farmers are often urged to transition to dryland crops rather than fallow their land after a water transfer has taken place, conversion to dryland farming has generally produced at least short-term negative regional economic impacts due to lower input requirements (Smith, 2005) and lower land values (Torell et al., 1990; Smith et al., 1996). And municipal compensation in the form of re-vegetation and payments-in-lieu-of-taxes for reduced land values do not replace the indirect and induced economic activity that is lost via irrigated agriculture's links to households and other industries in the regional economy, nor do they address the issue of sustaining agriculture as a viable profession for producers who want to stay in the business (Winner and Smith, 2008). It is no surprise then, that many rural communities view permanent water transfers as a threat to their economic foundation and future growth (Henderson and Akers, 2008). Other concerned stakeholders include urban residents, who benefit from the survival of farms and rural communities and believe it is important to maintain irrigated agriculture (Fix et al., 2001), and municipal water providers, some of whose reputations have been damaged by past "buy and dry" purchases.

It is no surprise then, that many rural communities view permanent water transfers as a threat to their economic foundation and future growth (Wilson, 1997; Henderson and Akers, 2008). Other concerned stakeholders include urban residents, who benefit from the survival of farms and rural communities and believe it is important to maintain irrigated agriculture (Fix et al., 2001), and municipal water providers, some of whose reputations have been damaged by past "buy and dry" purchases. Thus, stakeholders seek alternative methods for supplying growing cities with water (Poppleton, 2009). Indeed, in 2007 the Western Governors' Association and the Western States Water Council co -sponsored a conference entitled , "Water Policies and Planning in the West: Ensuring a Sustainable Future." Among the recommendations made by conference attendees of to address the ever-increasing challenges associated with water management in the West (W estern Governors' Association, 2008): maintaining family farming; identifying feasible alternatives to rural-to-urban water transfers; and finding innovative ways to allow transfers without damaging agricultural economies and environmental values, or infringing on private property rights.

Study Purpose

Because agricultural-to-urban transfers will continue to supply at least a portion of Colorado's future population growth, Nichols (2004) argues that the long-term challenge for Colorado is to manage these transfers in a way that minimizes negative impacts and fosters healthy agricultural economies and communities. Temporary leases have been proposed as an alternative means of securing water supplies during drought for urban and environmental uses

(Whittlesey et al., 1986; Hamilton et al., 1989; Huffaker et al., 1993; Nichols, 2004). Compared to permanent water transfers, water leases have the potential to improve efficiency and equity by reducing the amount of unused capacity during wet years and reducing the third-party impacts of water transfers.

Nonetheless, some agricultural water users are hesitant to admit they have excess water to transfer for fear they may lose their right (Emm et al., 2005; Kent, 2004; Green and Hamilton, 2000). Potential leasers and lessees may not be aware of their respective interest in effecting a transaction, or may have little or no basis on which to determine the reasonable lease prices, terms, and conditions (McCrea and Niemi, 2007). Although Colorado recently enacted legislation that authorizes a water right owner to lease water without formal adjudication of change of water right (CFWE, 2003), leasing of this type is rare in Colorado (Doherty, 2010) and it is unknown if Colorado farmers will participate in a lease market if one is established.

Among the necessary conditions for water lease markets are a critical mass of willing leasers and lessees, and sufficient gains from leasing to exceed transactions costs[15] (Michelsen and Young, 1993). The goal of this study is to provide insight into the potential for a water lease market in Colorado's South Platte Basin by assessing farmers' willingness to participate in a lease market, their desired lease payment and preferred terms of lease, and the amount of water that would likely be made available for lease. This is achieved via a survey of South Platte irrigators and subsequent analysis of survey responses. Three regression models are

[15] Transactions costs include but are not limited to the costs of collecting, conveying and treating water; legal costs, financing costs; and risk premiums. Transactions costs are discussed further in Chapter 4.

used to assess 1) farmers' willingness to lease, 2) farmers' desired payment for leasing, and 3) the number of acres fallowed by farmers as part of a lease.

Estimating a water supply function and determining the range of prices that irrigators expect in exchange for leasing their water will assist municipalities as they develop water supply plans and prepare financially for expected water supplies. Identifying factors that influence the lease decision and farmers' asking price for leased water will assist in the design of lease programs and policies, the financial planning for chosen programs, and the targeting of potential leasers. Understanding farmers' preferences for particular lease stipulations and how leases should best be negotiated and administered will guide the design and planning of such lease programs and increase the likelihood that the program participation. Allowing farmers to express their opinions and preferences may give them a greater sense of inclusion, control, and trust in the process, which may further increase participation.

Research results are particularly useful for policymakers who may need to alter existing institutions so that the transactions costs of leases do not outweigh the potential gains from trade. The results are also of interest other water stakeholders who are actively engaged in developing water-sharing alternatives and to farmers and municipal water providers that are contemplating the adoption of such alternatives. The next section discusses some of the features of water leases and describes two existing lease programs.

Water Leases

Leases can be beneficial to farmers because they maintain ownership of their water rights while receiving a predictable stream of revenue which could be used for farm improvements, debt reduction, new equipment, or capital for launching new agribusiness endeavors. The demand for leased water would be highest in dry years, which is precisely when a farmer's opportunity cost of letting some land lie fallow is lowest, so that the net income from a lease can exceed the revenue that would be realized from farming in these years (Colorado Water Conservation Board, 2007).

Leases can also provide benefits to municipalities by allowing them to access water much faster than purchasing water rights (Kimball, 2005) while avoiding the expense and complications of a permanent agricultural transfer or the liabilities and opportunity costs associated with the development of additional storage. Leases may be the least environmentally damaging alternative for providing additional municipal water supply to the Colorado Front Range (HDR Engineering, Inc., 2007) Finally, leases generate less opposition over potential third-party impacts than permanent transfers (Colby, 2007) and may reduce the amount of third-party compensation that municipalities are required to provide to areas-of-origin.

Making Water Available for Lease

Although appropriative water rights can be sold or leased, such transactions can inadvertently affect multiple parties since water rights often involve sequential users of the same water. A priority of Colorado water law is to protect other water right holders when water is transferred or leased; to this end, only the consumptive use (CU) component of a water right is eligible for transfer or lease. As such, a farmer must reduce the CU portion of his or her water right in order to make water available for lease. Water in excess of CU (e.g., ditch losses and return flows) would be returned to the river and used to satisfy other existing water rights (HDR Engineering, Inc., 2007). Improved irrigation efficiency is not likely to produce much transferable water because it results primarily in a reduced return flows rather than reduced CU (Trout et al., 2010). Two alternative methods of reducing CU—rotational fallowing and limited irrigation—are discussed next.

Rotational Fallowing

In a rotational fallowing arrangement, a large group of agricultural water right holders sign a lease agreement with a municipality. Each agricultural user agrees to withhold irrigation for one year out of a set period of years, and the saved water is transferred to the municipality. In this way, the municipality obtains a constant annual supply of water which comes from a different agricultural user each year, thus spreading the loss of agricultural activity over a greater area. The volume of water made available through rotational fallowing will depend on the participation rate and fallowing rate. The participation rate refers to the percentage of eligible irrigators who opt to join the program, while the fallowing rate refers to the frequency of the fallow rotation. For example, a 25 percent fallowing rate means that one quarter of all participating irrigators fallow their land in a given year.

Limited Irrigation

Another approach to reduce CU is to adopt limited irrigation techniques, whereby less water is applied than needed to meet the full evapotranspiration demand of the crop, after which the saved water can be leased. Limited irrigation techniques include choosing crops that use less water and timing irrigation to coincide with critical growth stages. Importantly, the limited irrigation cropland remains in production so that rural economies experience smaller reductions in economic activity relative to buy-and-dry activity. While crops under limited irrigation experience water stress and produce reduced yields compared to full irrigation, the economic activity generated by limited irrigation is greater than that for dryland cropping due to higher input requirements and sales (Pritchett, 2007; Schneekloth et al., 1995).

Potential Issues and Conflicts with Rotational Fallowing and Limited Irrigation

Soil, weed, labor, and equipment management issues must be considered during those periods when there is no irrigation. If crop changes are made, there needs to be a market for the new crop, and new farm equipment may be needed for planting and harvesting the new crop. The permanency of the water supply could be an issue for cities that need it every year, rather than in drought years only. There may be lower water availability during drought years if the one or more of agricultural providers is a junior right holder, in which case a portion of the allocation might not be available (McMahon and Reuer, 2007). A means for transferring the water to the urban region would be required, which may not be feasible or economical in all cases. A change-of-use permit would likely be required, the transferable amount would have to be determined, and other water users must be protected, although this would also be the case with a permanent transfer. And while water storage would be needed to firm the agricultural supplies and to replace delayed return flows from the fallowed lands; the amount of storage needed is expected to be less than that required for permanent water transfers.

Existing Lease Programs

In 2004, the Metropolitan Water District (MWD) and Palo Verde Irrigation District (PVID) in southern California approved a 35-year program that will pay farmers to annually set aside up to 29 percent of their land, rotate their crops, and transfer the salvaged water to metro areas, who declare a year in advance how much water they will buy. For each acre set aside, participating farmers receive a one-time payment of $3,170 and then $550 annually.

MWD has agreed to invest an additional $6 million in local community improvement programs. The land taken out of production is maintained and rotated once every one to three years, with none of the land permanently taken out of production (Letey, 2005). According to the general manager of the irrigation district, the land value has increased and farmers' incomes have become more stable (Sealover, 2007).

Inspired by the PVID in California, several ditch companies in the Lower Arkansas Valley Water Conservancy District (LAVWCD) in Colorado have joined to form the "Super Ditch", whereby shareholders fallowing a portion of their land on a rotational basis, pool the water savings, lease the water to municipalities, and then distribute the revenue to shareholders through dividends. The hope is that by working together in a rotational fallowing scheme, the ditch companies will have greater bargaining power, and by converting part of their land from growing hay or corn to growing "water", they could actually benefit financially and keep their agricultural communities viable (Winner and Smith, 2008). LAVWCD economic consultants reported that, when compared to permanent transfers, leasing shows a $10 to $30 million gain for the Valley.

Although the Super Ditch would be the first major project of its kind in Colorado, some small-scale fallowing and water leasing has occurred in the state. For example, the High Line Canal Company has contracted with the city of Aurora in a purchase/lease-back agreement in which Aurora owns the water and is leasing it back to farmers. Both sides have reported benefits (Sealover, 2007); however, the lease-back part of the agreement is expected to end in time. The Colorado-Big Thompson project in northern Colorado has allowed water to be rented on an annual basis between agricultural users and municipalities for over 50 years. However, because the project involves the trans-basin transfer of water, the water can be used to extinction, which is not the case for within-basin transfers, such as those being considered here. Aside from these programs, there are few instances in which water lease markets have been developed, and little attention has been given to them in the academic literature.

Analytical Framework

The Lease Decision

Following Zhou et al.'s (2008) analysis of the adoption of water-saving technologies in China, it is assumed that in deciding to lease their water, farmers weigh the expected utility from leasing—represented as $U^*(\pi_1)$, where π represents net farm returns—and the expected utility from not leasing—represented as $U^*(\pi_N)$. Underlying the discrete decision of whether or not to lease is a continuously-distributed variable representing the propensity to lease. While the parameters of this decision are not observable, they can be represented by a latent variable which equals one if $U^*(\pi_1) > U^*(\pi_N)$ and zero otherwise, assuming that farmers are risk-neutral. The utility from leasing can be expressed as:

$$Y(\pi_1) = \mathbf{X}_i\beta + \varepsilon_i \quad (31)$$

where $\mathbf{X}$ is a vector of variables expected to influence the lease decision; β is a vector of parameters to be estimated, and ε is a random error term. The probability that respondent i is willing to lease his or her water can be expressed as:

$$P(Y_i = 1 \mid \mathbf{X}_i) = P(U^*(\pi_1) > U^*(\pi_N)) = P(\varepsilon_i > -\mathbf{X}_i\beta) = 1 - F(-\mathbf{X}_i\beta) = F(\mathbf{X}_i\beta) \quad (32)$$

where F is the cumulative distribution function (cdf). Specifying a standard logistic cdf yields the logit model, which has become the standard approach to qualitative dependent variable analysis and was discussed in greater detail in Chapter 3. In the present analysis, the odds that a respondent is willing to lease can be defined as the ratio of the probability p of a response of *agree* or *strongly agree*, to the probability $1 - p$ of a response of *disagree* or *strongly disagree*. The log of this ratio yields the logit model (Collett, 2002):

$$\ln[p_i/(1-p_i)] = \mathbf{X}_i\beta + \varepsilon_i, \tag{33}$$

where the elements of **X** are factors that are expected to influence the probability of a response of *agree* or *strongly agree* to the leasing statement. The variables used to measure these factors are discussed in the Methodology and Data section that follows.

Acres Fallowed and Required Remuneration

Identifying the factors that influence the number of acres fallowed by willing leasers will provide further insight into the leasing decision and will assist water providers in predicting the amount of water that might be leased basin-wide. Identifying some of the factors that influence the payment required by farmers to lease their water will assist water providers as they consider water supply options and plan financially for those supplies.

But before a farmer decides the minimum lease payment to require or the amount of land to fallow as part of a lease, the farmer must first make the decision to participate in a lease program. Thus, to model these decisions, a two-step estimation procedure is used in which a full-sample logit estimation of the decision to lease is followed by a censored estimation carried out on the subsample of participants who are willing to lease. The first step estimates the probability of observing a positive lease decision, while the second estimates the number of acres fallowed or the payment required conditional on observing positive values (Dow and Norton, 2003). This approach, attributed to Heckman (1979), can be viewed as a generalized version of the Tobit model that recognizes the process to be a two-stage decision and permits the use of a different set of explanatory variables in each stage of estimations (Wodjao, 2007).

Following McDowell (2003), let $F_1(\beta_1)$ represent the probability that the hurdle is crossed, and let $f_2(y, \beta_2)/F_2(\beta_2)$ be the conditional distribution of the positive responses, where $y \in \Gamma_+$, f_2 satisfies $\sum_{y \in \Gamma_+} f_2(y, \beta_2) = 1$, F_2 is the summation of f_2 on the support of the conditional density (i.e., the truncation normalization), and $y \in \Gamma_+ = \{1, 2, 3, \ldots\}$. The general form of the hurdle model likelihood function is then:

$$L = \prod_{i \in \Omega_0} \{1 - F_1(\beta_1)\} \prod_{i \in \Omega_1} \frac{\{f_2(y, \beta_2) F_1(\beta_1)\}}{F_2(\beta_2)} \tag{34}$$

Where $\Omega_0 = \{i \mid y_i \neq 0\}$, and $\Omega_0 \cup \Omega_1 = \{1,2, \ldots, N\}$. Taking the natural logarithm of both sides and rearranging yields:

$$\ln(L) = \sum_{i \in \Omega_0} \ln\{1 - F_1(\beta_1)\} + \sum_{i \in \Omega_1} \ln\{F_1(\beta_1)\} + \sum_{i \in \Omega_1} \left[\ln\{f_2(y, \beta_2)\} - \ln\{F_2(\beta_2)\} \right] \tag{35}$$

Because the likelihood function is separable with respect to the parameter vectors β_1 and β_2, the log likelihood can be written as the sum of the log likelihoods from two separate models: a binomial probability model and a truncated-at-zero count model. As such, the hurdle model log-likelihood can always be maximized without loss of information by maximizing the two components separately. Thus, the parameters can be estimated by fitting the two component models separately (McDowell, 2003), which is the approach adopted here.

Methodology and Data

Study Area

Colorado's South Platte Basin serves as an appropriate and important region in which to examine the viability of water leases as an alternative to permanent water transfers. The basin contains the majority of the state's population and its most productive irrigated agricultural lands, yet has only 12 percent of its water supply (South Platte Research Team, 1987). The basin is expected to bear the majority of Colorado's population growth, with two million additional residents projected to live there by 2030, requiring approximately 410,000 AF of additional water. Most water managers in the region have realized it is no longer possible to rely on strategies based solely on expanding supply (Goemans, 2007), and water conservation efforts are expected to satisfy only 16 percent of the increased demand (Colorado Conservation Board, 2005). In fact, most providers in the basin have indicated that they would be more likely to acquire additional agricultural rights than to implement aggressive levels of conservation. Indeed, up to 226,000 irrigated acres (nearly a quarter of all irrigated cropland in the basin) are expected to be dried up to meet future M&I needs. An additional 10,000 to 20,000 acres are expected to be lost as a result of new augmentation rules.

Limiting the study area to the South Platte Basin allows the research questions to be answered within time and budget constraints and without diluting the results with an overly broad study area. The results can guide similar research in other regions and can be combined with Census data to predict water lease supplies and prices in other regions.

Producer Survey

In the first phase of the study, NASS mailed a questionnaire to all South Platte basin farmers who reported having more than fifty irrigated acres in the 2002 Census of Agriculture. Mailing began during the first week of September 2007 using procedures outlined by Dillman (2007), with a postcard reminder mailed ten days later and a second survey mailing twenty-one days after the initial mailing. The survey consisted of three main sections: 1) farmer demographics; 2) farm characteristics, including irrigation water source, crop rotation, and financial standing; and 3) attitudes about leasing arrangements, including willingness to participate, acres fallowed, desired compensation, and desired contract provisions. The full survey is available from the author upon request.

Attitudinal Questions

The attitudinal questions were posed in the form of a Likert scale which measured the extent of agreement with each statement as indicated by selection of one of five responses: *strongly disagree, disagree, neither agree nor disagree, agree,* or *strongly agree.* Responses of *strongly agree* were given a value of 5, whereas responses of *agree, neutral, disagree,* and *strongly disagree* were given values of 4, 3, 2, and 1, respectively.

Willingness-to-Accept Question

Stated preference methods attempt to place values on goods and services that cannot be related to direct market transactions, such as leased water in the present case. Stated preference surveys have employed a variety of question formats to elicit WTP or WTA values. These include the open-ended format, whereby respondents are asked directly to state their maximum WTP (or minimum WTA), and the dichotomous choice (DC) format, whereby respondents are offered a particular price and then asked whether or not they would pay it. The DC format is less efficient than the open-ended format, requiring substantially larger samples for a given level of precision (Loomis et al., 1997). This is an issue of particular concern in the present case; thus, the open-ended approach was used here to elicit farmers' minimum WTA to lease their water.

When designing and implementing a lease program, it is useful to know some of the key characteristics and factors that influence a farmer's decision to lease his or her water, the number of acres fallowed by those farmers who are willing to lease, and the payment requested in return. Each of these decision variables was regressed on survey data, as described next.

Modeling the Decision to Lease

Dependent Variable

Willingness to Lease serves as the dependent variable in the logit model, and is based on agreement with the statement, "I am willing to lease rather than sell my water rights". This variable is made binary by giving responses of *disagree* or *strongly disagree* a value of zero and responses of *agree* or *strongly agree* a value of one.

Explanatory Variables

Farmers rarely give consideration to a new practice unless it is profitable (Havens and Roger, 1961). However, as pointed out by Saltiel et al. (1994), the more important issue may be farmers' *perceptions* of the profitability of a practice—and other virtues of the practice, as argued here. By incorporating such perceptions into a model, it is possible to identify factors that affect the decision to lease independent of net economic returns. Factors that place constraints on an operator's ability to adopt a new practice also need to be taken into account (Heffernan, 1984; Nowak, 1984; Sommers and Napier, 1993). For example, because ground water cannot currently be leased, farmers with a large proportion of ground water might not participate in a lease program regardless of their perceptions of the program. Other factors that are expected to influence a farmer's decision to lease include characteristics of the farm operation; future plans of the farmer; and demographic characteristics of the farmer, especially those frequently associated with innovation, such as age and education (Rogers, 1983). Each of these is discussed next.

Characteristics of the farm

Debt: A high debt-to-asset ratio might encourage farmers to lease their water to provide a stable source of income that could be used to service debt. On the other hand, a high debt-to-asset ratio might instead encourage some farmers to sell their water rights and exit the business. This discrete variable indicates a farmer's self-reported debt-to-asset ratio.

Percent Groundwater: Ground water rights are not eligible for lease, so that a higher percentage of ground water in the water portfolio is expected to lead to a lower likelihood of leasing. This continuous variable indicates the percentage of a farmer's irrigation water that is from groundwater.

Irrigated acres: Farm size is usually shown to be positively related to the speed and intensity of adoption of a new agricultural technology (Feder and O'Mara, 1981). A larger number of irrigated acres also implies a larger quantity of water available for lease. The average respondent owned 351 irrigated acres.

Urban Proximity: Farmers on the urban-rural fringe may feel increased pressure to sell their land for development and sell their water rights to municipalities. This dummy variable indicates a county's adjacency to U.S. Interstate 25, which runs along Colorado's urban Front Range corridor.

Well Shut-Down: In 2006, the State Engineer curtailed the pumping of 440 ground water wells as temporary water replacement plans were no longer accepted for augmenting out-of-priority pumping (permanent augmentation plans were instead required). This affected roughly eight percent of all South Platte irrigators, yet fully twenty percent of survey respondents reported having had their well(s) shut down. These farmers may be less sympathetic toward cities' water needs, and may thus be less likely to lease. On the other hand, they may have a heightened awareness of water scarcity and may be more likely to lease as one of few options available to sustain irrigated agriculture.

Farmer attitudes and plans

Willingness to work with municipalities in arranging lease agreements: Farmers who are not willing to negotiate with municipalities may be less likely to lease their water for the sake of avoiding "helping" these municipalities or having to interact with them.

Willingness to work with other organizations in arranging lease agreements: If a lease agreement can be negotiated via a neutral third-party, famers may be more likely to consider leasing.

Plans to upgrade, modify, or replace the irrigation system: Plans to upgrade the irrigation system indicate a higher level of investment in farming and should, all else equal, increase the likelihood of entering into a lease. Fifty-four percent of respondents had such plans.

Plans to sell water rights: If a farmer sells his or her water rights, that water will no longer be available for lease.

Belief that leases will be more beneficial to rural communities than the sale of water rights: A farmer who holds this belief may be more likely to lease his or her water out of concern for the local community.

Belief that leases can be a source of revenue for farmers: Farmers who believe that water leases can be beneficial to farmers will be more likely to enter into such an agreement.

Belief that leases can reduce the risk of the farmer's own operation: Farmers will be more likely to enter into a lease agreement if they believe it will be beneficial to them personally.

Belief that water leases will help meet Colorado's future water needs: Farmers will be more likely to enter into a lease agreement if they believe it will be beneficial to their fellow Coloradans.

Demographic and socioeconomic characteristics of the farmer

Farming Experience: A farmer with more experience has likely invested more time and money into the farming operation and way of life and may have more ties to the local community, and may thus be more willing to enter into a lease agreement if it means keeping their farm in operation. On the other hand, a farmer with a lot of experience may be nearing retirement. If this farmer has no plans to pass the farm onto younger family members, he or she may be more likely to sell, rather than lease, his or her water rights. The average respondent had 36 years of farming experience.

Education Level: Farmers with more education may have had earlier and more frequent exposure to the idea of water leases. Such farmers may also have greater confidence in their farm management skills, knowledge of western water law, and negotiation skills, which may translate into greater confidence to explore the option of leasing. Huffman (2001) found that farmers who were better educated had a greater ability to acquire and process information and were more able to evaluate critically the productive characteristics and costs of adopting innovative technologies than those less educated. On the other hand, farmers with more education may have a greater set of alternative employment options, such that they are less dependent on farm income and are more likely to sell out.

Second Job: A farmer who has an off-farm job may have less need for income from the farm and may thus be more likely to sell his or her water rights so that the revenues can be invested elsewhere. On the other hand, a farmer who has an off-farm job may be less susceptible to the pressure to sell their water rights inasmuch as he or she has a less immediate need for the income from such a sale. Forty percent of respondents had a second job in addition to their farm operation.

Table 29 provides a brief description of the explanatory variables, while Tables 30 and 31 contain the coefficients of correlation between these variables.

Table 29: Explanatory Variables, Description, and Expected Sign

Variable	Description
Experience	Years of farming experience
Experience^2	Years of farming experience squared
Beneficial for rural communities	Level of agreement with the statement, "Water leases are more beneficial to rural economies when compared to the sale of water rights."
Source of revenue for farmers	Level of agreement with the statement, "leases can be a source of revenue for farmers."
Reduce financial risk of my farm	Level of agreement with the statement, "Water leases would reduce financial risk in my farming operation."
Meet Colorado's water needs	Level of agreement with the statement, "Water leases between agriculture and cities will help meet Colorado's future water needs."
Second Job	Dummy variable indicating farmers that have an off-farm job.
Debt	Dummy variable indicating a debt-to-asset ratio greater than 0.40.
Education Level	A 6-point scale ranging from elementary education to graduate school.
Irrigated Acres	Number of irrigated acres owned by the farmer.
Well Shut-Down	Dummy variable indicating farmers who had their wells shut down in the past year.
Urban Proximity	Dummy variable signifying adjacency to U.S. Interstate-25.
Plans to Upgrade Irrigation System	Dummy variable indicating farmers who have plans to upgrade or modify their existing irrigation system in the next 5 years.
Work with municipalities	Level of agreement with the statement, "I am willing to negotiate directly with a municipality to establish a water lease arrangement."
Work with other organizations	Level of agreement with the statement, "I am willing to work through another organization when signing lease arrangements."

Table 30: Correlation Coefficients among Explanatory Variables

	Experience	Leases better for rural communities	Education level	% Ground Water	Irrigated acres	Plan to sell water rights	Plan to upgrade	Second job	Urban Proximity
Leases better for rural communities	-0.07	1.00							
Education level	-0.24	0.12	1.00						
% Ground Water	0.12	0.01	-0.06	1.00					
Irrigated acres	0.04	0.01	0.05	0.18	1.00				
Plan to sell water rights	0.03	-0.10	0.05	-0.07	-0.06	1.00			
Plan to upgrade	0.03	0.10	0.10	0.00	0.11	-0.06	1.00		
Second job	0.01	0.05	0.06	-0.07	-0.03	-0.01	-0.06	1.00	
Proximity to urban center	0.05	-0.10	0.03	-0.25	-0.02	0.03	-0.04	-0.01	1.00
Work with other organizations	-0.08	**0.33**	0.07	0.11	0.08	0.03	0.05	-0.07	-0.04
Work with municipalities	-0.14	0.17	0.03	0.05	0.16	0.10	0.01	-0.02	0.04
Owner-operator	-0.05	0.12	-0.05	-0.10	0.05	0.01	0.03	0.05	0.16
% Irrigated Sales	-0.07	-0.07	-0.01	-0.08	0.19	0.02	0.03	-0.15	0.23
Leases will help meet future water needs of Colorado	-0.03	0.28	0.09	0.03	0.15	0.08	-0.01	0.01	0.03
Leases can reduce the risk of my farm operation	-0.14	0.07	0.10	0.00	0.07	0.08	-0.06	-0.03	-0.01
Source of revenue for farmers	-0.15	0.33	0.12	-0.11	0.03	0.05	0.04	0.01	0.11
Debt	-0.17	0.10	-0.05	0.11	0.07	0.06	0.06	0.09	-0.20
Well Shut-Down	0.00	-0.03	-0.02	-0.11	0.05	-0.14	-0.06	0.02	0.39

Table 31: Correlation Coefficients among Additional Explanatory Variables

	Work with other organizations	Work with municipalities	Owner-operator	% Irrigated Sales	Leases will help meet water needs in CO	Leases can reduce my farm's risk	Source of revenue	Debt	Well Shut-Down
Work with municipalities	**0.37**	1.00							
Owner-operator	0.00	-0.05	1.00						
% Irrigated Sales	0.03	-0.04	0.13	1.00					
Leases will help meet future water needs in CO	**0.40**	**0.45**	0.03	0.00	1.00				
Leases can reduce the risk of my farm operation	0.25	0.30	-0.13	-0.09	0.28	1.00			
Source of revenue for farmers	0.29	0.25	0.18	0.05	0.39	0.17	1.00		
Debt	0.17	0.10	0.07	-0.05	0.05	0.03	0.02	1.00	
Well Shut-Down	-0.12	-0.02	0.14	0.24	-0.12	-0.05	-0.08	0.02	1.00

The largest coefficients of correlation were positive and occurred between attitudinal variables. The belief that leases will help meet Colorado's future water needs is positively correlated with a willingness to work with both municipalities and other organizations. Additionally, willingness to work with municipalities is positively correlated with willingness to work with other organizations.

Modeling the Requested Lease Payment and the Amount of Land Fallowed

Dependent Variables

An open-ended WTA question produces a set of welfare measures for the *n* respondents in the sample. These responses can be regressed on income and other socioeconomic characteristics to obtain a mathematical relationship indicating the importance of these variables on the payment amount required by farmers to enter into a lease agreement. Then, data on the characteristics of the relevant population can be used to calculate WTA for each member of the population (Freeman, 2003, p. 164). Because an open-ended question format was used for these questions, these decision variables are continuous and can be modeled via OLS.

Explanatory Variables

While many of the factors that are expected to influence a farmer's decision to enter into a lease agreement are also expected to influence the number of acres fallowed as a part of that lease, there are some additional factors that are expected to specifically affect this decision. For instance, the higher the price a farmer expects to receive per acre as part of a lease agreement, the more acreage that farmer is expected to be willing to fallow. Thus, each farmer's stated WTA amount is included in the regression. The structure of the lease payment may also affect the number of acres fallowed and is similarly included. A farmer's tillage practices may affect the ease with which a field can be fallowed, and is thus also included.

Many of the same explanatory variables used in the previous two models are also expected to influence the payment required by a farmer in return for leasing his or her water. Additional variables thought to influence the decision include:

Ditch Company: This dummy variable indicates the proportion of a farmer's water that comes from a ditch company. Ditch companies were the top source of irrigation water for respondents, supplying just over 55 percent of all respondents' water.

Annual Gross Sales: A farmer's current revenues will likely influence his or her expectations for future revenues and thus the required remuneration for a lease. The average annual gross sales for all willing leasers was $516,837.

Long-Term Lease: Farmers who prefer a long-term lease may be willing to receive a lower price in exchange for the security of a longer lease. On the other hand, knowing that cities desire long-term leases may spur such farmers to request a higher price.

Acres Fallowed: The number of acres a farmer fallows as part of a lease agreement may influence the desired payment per acre for doing so. For instance, it may be more cost-effective to fallow larger parcels of land, thus requiring a smaller payment per acre. On the other hand, taking more land out of production may involve the more productive plots of land, thus requiring a higher payment per acre.

Center Pivot: Different irrigation methods entail different operation and maintenance costs, which may affect a farmer's desired lease payments. Sixty percent of willing leasers reported using a center pivot sprinkler system, irrigating an average of 76 percent of their acreage via center pivot sprinkler.

The next section begins with a summary of the survey responses. This is followed by an exposition of the regression analyses just described.

Results and Discussion

A survey was used to assess whether farmers are willing to sign leases if suitably compensated; what compensation is needed, and how much water farmers would be made available for lease. Of the 1,731 successful mailings, 329 usable surveys were returned, yielding a response rate of 19 percent. Further adjustment of the respondents for item non-response resulted in a final sample of 191. Low response rates are a pervasive problem when conducting surveys, and may limit the ability to make generalizations about the results if survey respondents are not representative of the study population. Because U.S. Census data are not reported for particular segments of the population, such as farmers, the average demographics of South Platte Basin farmers are not known and cannot be compared the demographics of survey respondents. Nevertheless, data from NASS can be used to compare respondents to the average South Platte farmer according to age, location, crop-mix, farm size.

The average age of survey respondents (58 years) was very similar to that of all South Platte farmers (54 years). The responses originated from counties in a pattern generally representative of the distribution of irrigated farms in the South Platte Basin, with proportionately more surveys coming from those counties with proportionately more irrigated farms. Forty-five percent of all returned surveys came from Weld County. This was followed by Morgan County (23 percent), Larimer and Logan Counties (just over 11 percent each), with the remaining counties making up the remaining ten percent of responses.

Because the survey asked farmers about their *anticipated* crop-mix for 2008, the responses are not expected to coincide exactly with the crop-mix in the entire South Platte Basin in 2007. Nonetheless, we can compare relative crop proportions to look for any irregularities. As shown in Table 32, survey respondents have nearly the same relative crop-mix as would be expected[16]. Although survey respondents planned to plant relatively more corn silage and relatively less corn grain than the average South Platte Basin farmer planted in

[16] Proportions were calculated for only those crops that were reported both in the survey and in NASS.

2007, *total* corn acres (the sum of corn for grain and corn for silage) were very comparable. Furthermore, silage is sometimes a harvest-time decision, rather than a planting-time decision.

Table 32: Crop-Mix Comparison between Survey Respondents and South Platte Basin Farmers

Crop	South Platte (2007)†	Survey Respondents (Planned for 2008)
Corn Grain	55.5%	35 5%
Hay	26.9%	32.2%
Corn Silage	2.7%	14.6%
Wheat	10.4%	11.7%
Sugar Beets	2.6%	3.1%
Dry Beans	1.8%	2.9%

†Source: National Agricultural Statistics Service

While survey respondents had crop-mixes that were very similar to that of the entire Basin, their farms tended to be larger than the Basin-wide average[17]. This is not unexpected—those with larger farms may have stronger opinions about agriculture and more incentive to express those opinions in a survey. More detail is shown in Table 33, which shows the distribution of farms by size for survey respondents and for the entire Basin. The difference in farm size between the sample and population, especially in the case of the largest size category, warrants the use of weights. Thus, the stated WTA amounts were weighted by farm size to better represent the true population of South Platte farmers.

Table 33: Comparison of Respondents' Farm Size to South Platte Basin Average

Farm Size (acres)	50-179	180-499	500-999	1,000 or more
Survey Respondents	34.3%	30.0%	16.8%	18.9%
SP Basin†	32.8%	22.4%	13.9%	30.9%

†Source: National Agricultural Statistics Service

Leasing Attitudes

Figure 8 displays respondents' general beliefs regarding the merits of water leases. Irrigators appear to have a positive view of water leases in general but are less certain about the benefits that leases would provide them personally, which may stem from a lack of personal

[17] Respondents' average farm size was 1,141 acres, while the average for the South Platte Basin was 990 acres.

experience with water leasing. While fewer than half of respondents believe leases would reduce the financial risk of their *own* farming operation, the majority of respondents believe that water leases can be a source of revenue for farmers in general and are more beneficial to rural communities than are water sales. A smaller majority agree that water leases will help meet Colorado's future water needs. Because additional reservoir projects, increased municipal conservation, and inter-basin pipelines are generally supported by Colorado's agricultural organizations, respondents may see leases as just one part of the solution to complex water demand issues. Fewer than seven percent of respondents expect to sell their water rights within five years, which is encouraging for the establishment of a lease program.

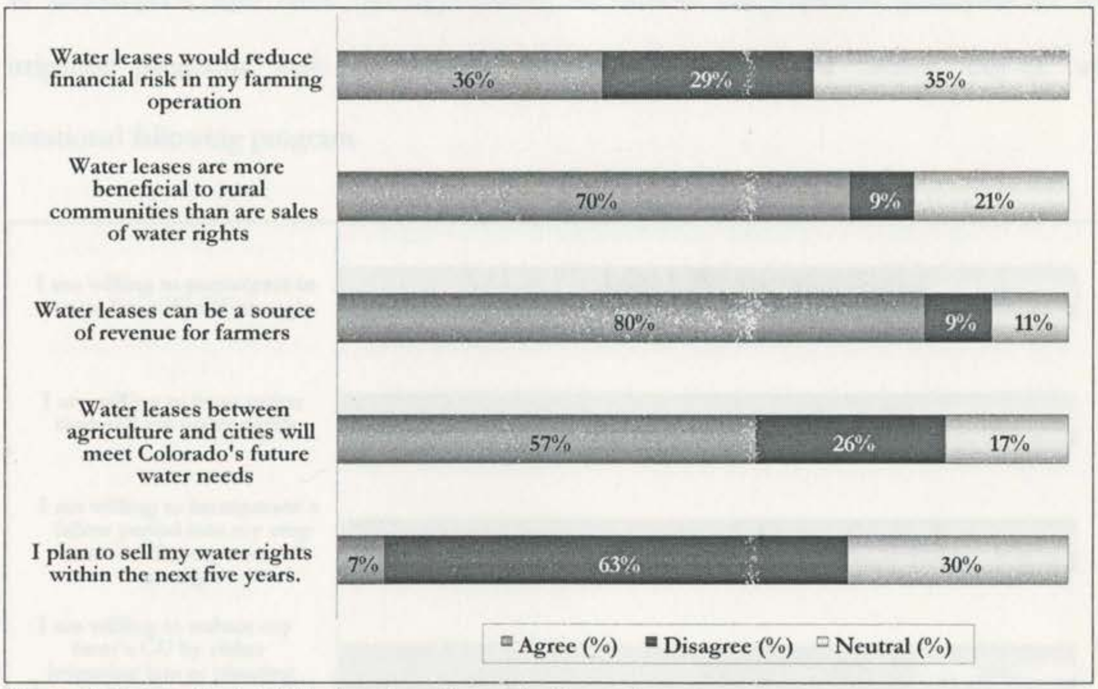

Figure 8: Respondents' Attitudes about Leases in General

Figure 9 displays respondents' willingness to participate in water lease arrangements. The nearly identical responses to the first two statements provide evidence of the internal validity of the survey and provide evidence that the majority of farmers would be willing to lease their water under certain conditions. While rotational fallowing is acceptable to 63 percent of respondents, fewer respondents are willing to adopt limited irrigation strategies. Farmers may be more hesitant to adopt limited irrigation programs because the agronomical and financial ramifications of such programs are less familiar and less certain. Under limited irrigation, the farmer would be trying new crop mixes and/or timings of irrigation timing, etc., that are unfamiliar and yield uncertain outcomes. Under a fallowing program, on the other hand, yields and revenues can be better predicted—namely, zero when fallowing and typically expected full-irrigation values when irrigating. Additionally, limited irrigation programs may require more intense management, which may discourage adoption. This information is useful to researchers, who have the opportunity to explore the expected outcomes of limited irrigation programs, and policymakers, who may garner greater farmer "buy-in" with a rotational fallowing program.

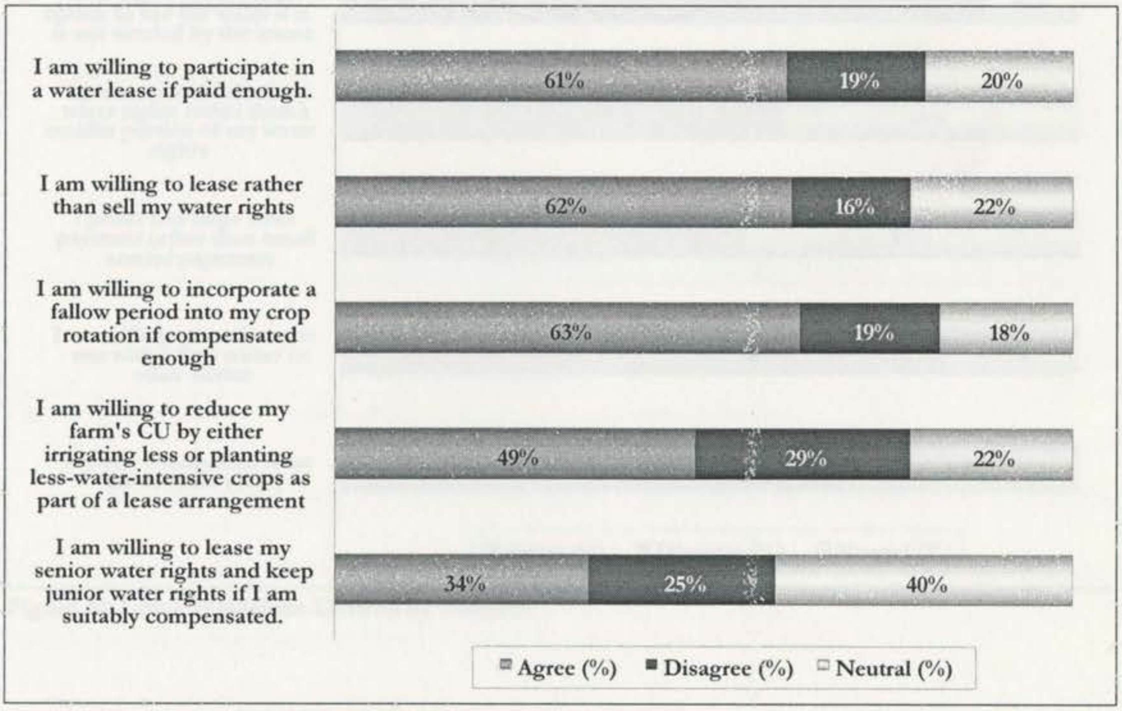

Figure 9: Respondents' Willingness to Participate in a Lease

Lease Preferences

Figure 10 displays some of the lease provisions desired by respondents. Not surprisingly, a large majority of respondents prefer a lease agreement in which they have the first option to use the water if it is not needed by the water leaser. More respondents prefer to lease a portion, rather than all, of their water rights. Additionally, more respondents prefer smaller annual payments rather than one large payment, most likely for tax purposes. Respondents are evenly split in their preferences regarding the length of the lease: 32 percent prefer a long-term lease, 38 percent do *not* prefer a long-term lease, and the remaining thirty percent are neutral, which suggests that any number of lease lengths would be acceptable to farmers. This leaves municipalities with ample room to negotiate and good prospects for satisfying their preferences regarding this feature of the lease.

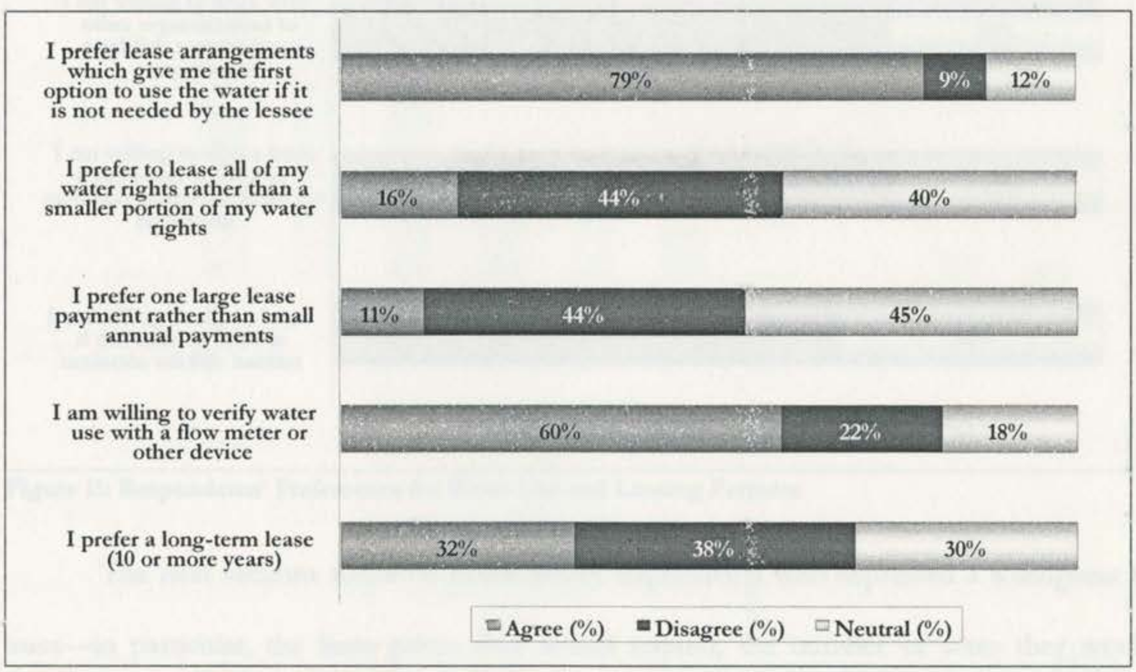

Figure 10: Lease Provisions Desired by Farmers

Figure 11 displays additional provisions that respondents prefer in leases and the lease negotiation process. Less than half of all respondents are willing to negotiate directly with a municipality to lease water, perhaps leaving negotiations to their existing ditch companies, mutual associations, or another institution that may evolve in the future. Indeed, a greater percentage of respondents are willing to negotiate with other organizations when developing lease agreements. Although the majority of respondents responded favorably regarding a willingness to lease, a much smaller proportion of respondents would be willing to lease their water if that water was used for wildlife or recreational purposes.

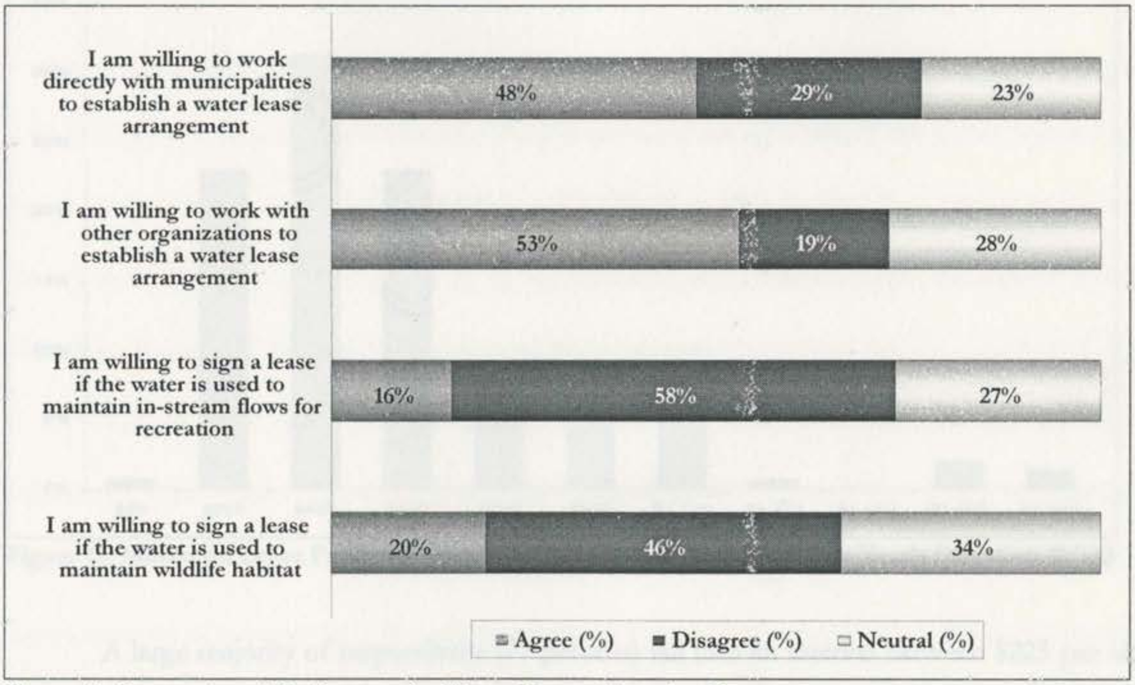

Figure 11: Respondents' Preferences for Water Use and Leasing Partners

The next sections focus on those survey respondents who expressed a willingness to lease—in particular, the lease prices they would request, the number of acres they would fallow, and the characteristics that distinguish them from non-leasers.

Pricing Water Leases

Whether a viable lease market will emerge depends critically on whether the cost of leases is in line with what municipalities are willing and able to pay. In an open-ended WTA question, respondents were asked to indicate the minimum price they would have be paid in order to forgo irrigation for one year as part of a fallow-lease arrangement. Their responses appear in the histogram in Figure 12. Price intervals are displayed along the horizontal axis, with each label referring to that interval's uppermost bound. The proportion of respondents that fall within each interval is measured on the vertical axis.

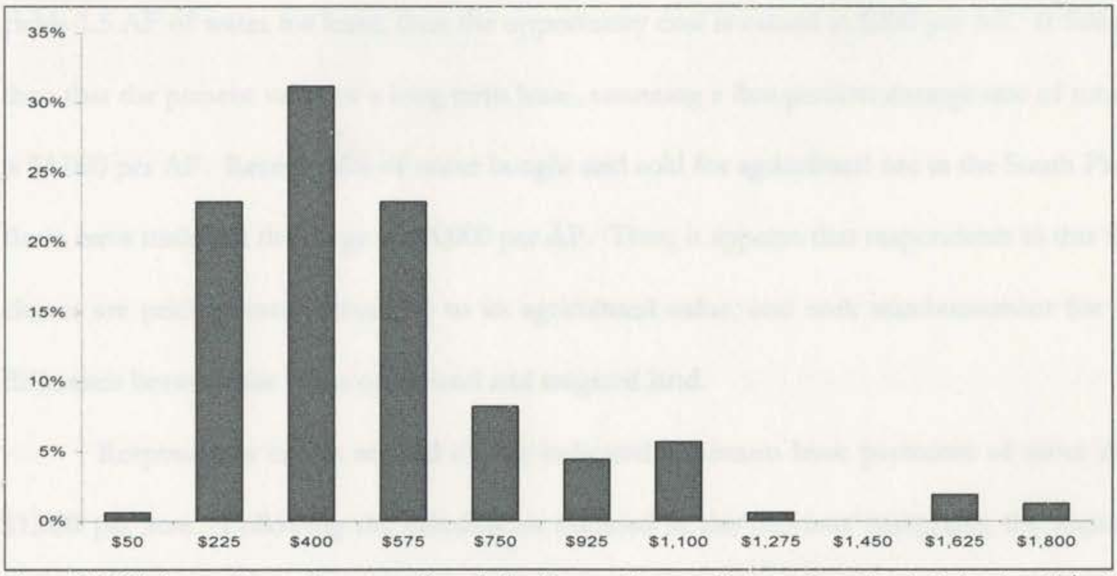

Figure 12: Minimum Lease Payments Sought by Respondents to Forego One Year's Irrigation ($/ac)

A large majority of respondents (77 percent) fall into an interval between $225 per acre and $575 per acre. While the average application rate is 2 AF per acre in the South Platte Basin, maintaining return flows for downstream irrigators would likely result in approximately 1.5 AF per acre being supplied to cities as a result of a sale or lease, yielding a price range of

$150 to $383 per AF. Assuming a five percent rate of return on investment in agriculture, the present value[18] of a long-term lease would amount to $3,000 to $7,667 per AF.

A market analogy can be found for the lower end of this interval: At the time the survey was received, cash rent for irrigated cropland averaged $300 per acre with dryland alternatives netting less than $50 dollars per acre. The opportunity cost of forgoing irrigating cropping can be considered the difference between irrigated and dryland cash rents plus the cost of weed management and irrigation equipment maintenance. If this opportunity cost is $300 per acre ($250 for lost rents plus $50 for management costs), and if each acre fallowed yields 1.5 AF of water for lease, then the opportunity cost is valued at $200 per AF. It follows then that the present value of a long term lease, assuming a five percent average rate of return, is $4,000 per AF. Recent sales of water bought and sold for agricultural use in the South Platte Basin have traded in the range of $3,000 per AF. Thus, it appears that respondents in this first cluster are pricing water according to its agricultural value, and seek reimbursement for the difference between the value of dryland and irrigated land.

Respondents in this second cluster indicated minimum lease payments of more than $1,000 per acre. Following the calculations outlined in the previous paragraph, the imputed value of water in this instance is $20,000 per AF or more. Interestingly, this value is representative of recent sales of agricultural water bound for municipal use (Water Colorado, 2009). Perhaps, then, these farmers seek reimbursement for forgoing the opportunity to sell the water to municipalities, rather than reimbursement for forgoing irrigation.

[18] The present value of payments made in perpetuity can be calculated by dividing the payment amount by the assumed rate of return.

The WTA responses were weighted by farm size to better represent the entire population of South Platte farmers, yielding a mean WTA of $543 per acre ($362 per AF) and a median WTA of $373 per acre ($249 per AF). To provide further detail and increase the precision of projections, mean and median WTA were also calculated for each farm size category (Table 34). In cases where the mean differs markedly from the median, the median is often chosen as the preferred measure because it is not influenced by extreme values in the sample; thus, subsequent discussions and analyses focus on median WTA.

Table 34: Weighted Average Willingness-to-Accept Amount by Farm Size

Farm Size (acres)	50-179	180-499	500-999	1000 or more
Weighted Mean WTA per acre	$443	$475	$595	$817
Weighted Median WTA per acre	$336	$354	$331	$653

Are these Prices Reasonable?

The South Platte respondents' stated lease prices can be compared to the net receipts that farmers currently receive by using the water to irrigate crops. Farmers should be expected to require some premium above what they receive from their water rights in their current use—to offset the transactions costs of negotiating a water lease, to fund the upkeep of fallowed fields and idle machinery, and to compensate for the uncertainty entailed by an untested lease market. The net receipts from irrigated land vary by crop and year, but recent figures nonetheless provide some perspective: in 2007, net receipts before factor payments ranged from $47/acre for corn for grain to $311/acre for pinto beans. The weighted average of net receipts based on the overall crop-mix in the South Platte Basin is roughly $110/acre. This is very similar to the average cash rent per acre of irrigated cropland in Colorado, estimated to be $100 in 2007 (Colorado Agricultural Statistics, 2008).

The lease prices can also be compared to municipal water providers' value of the water. The "avoided cost" approach estimates the value of water for municipal supply by the amount a city would spend to develop an alternative source of water. Presumably, the maximum amount a city would offer for leased water is its avoided cost for an alternative supply, minus the conveyance and treatment costs. HDR Engineering, Inc. (2007) compiled a range of raw water supply costs for a number of Front Range water providers. Then, based on preliminary estimates of conveyance costs, they estimated the amount that would be left over to bid for a leased rotational-fallowed water supply. These estimates ranged from $50 per AF in a wet year to $850 per AF in a dry year. Because avoided costs tend higher in the northern Front Range than in the Arkansas Valley, municipalities in the South Platte Basin may be willing to pay even higher prices.

Finally, respondents' desired prices can be compared to water trades that have already taken place. A 40-year "Super Ditch" lease carries a base price of $500 per AF per year (Nichols, 2010). In its arrangement with the Rocky Ford Highline Canal, the city of Aurora paid irrigators approximately $300 per AF (HDR Engineering, Inc., 2007). In Colorado towns on the eastern slope of the Rocky Mountains, the rights to an allotment of water brought a price of $1,900 in 1981. Annualizing and converting to acre-feet yields an average water value of approximately $300 per AF (or $594 per AF in 2008 dollars). In the Colorado Big Thompson water market, water prices surged to over $13,000 per AF during the drought of 2002. Using data from the *Water Strategist*, Brewer et al. (2007) found that the average price of water leased from agricultural users to urban users between 1999 and 2002 was $114, while the median price was $40. The prices sought by South Platte respondents thus appear to be within the range that cities might be willing to pay.

There is some correlation between farm location and minimum WTA. The largest share of respondents requesting more than $600/acre were located in Morgan County. The sole respondent from Adams County also requested a payment above $600/acre. In contrast, the largest share of respondents requesting less than $400/acre were located in Weld County. The sole respondent from Yuma County also requested a payment below $400/acre. For reference, Figure 13 contains a map of the Colorado portion of the South Platte River Basin.

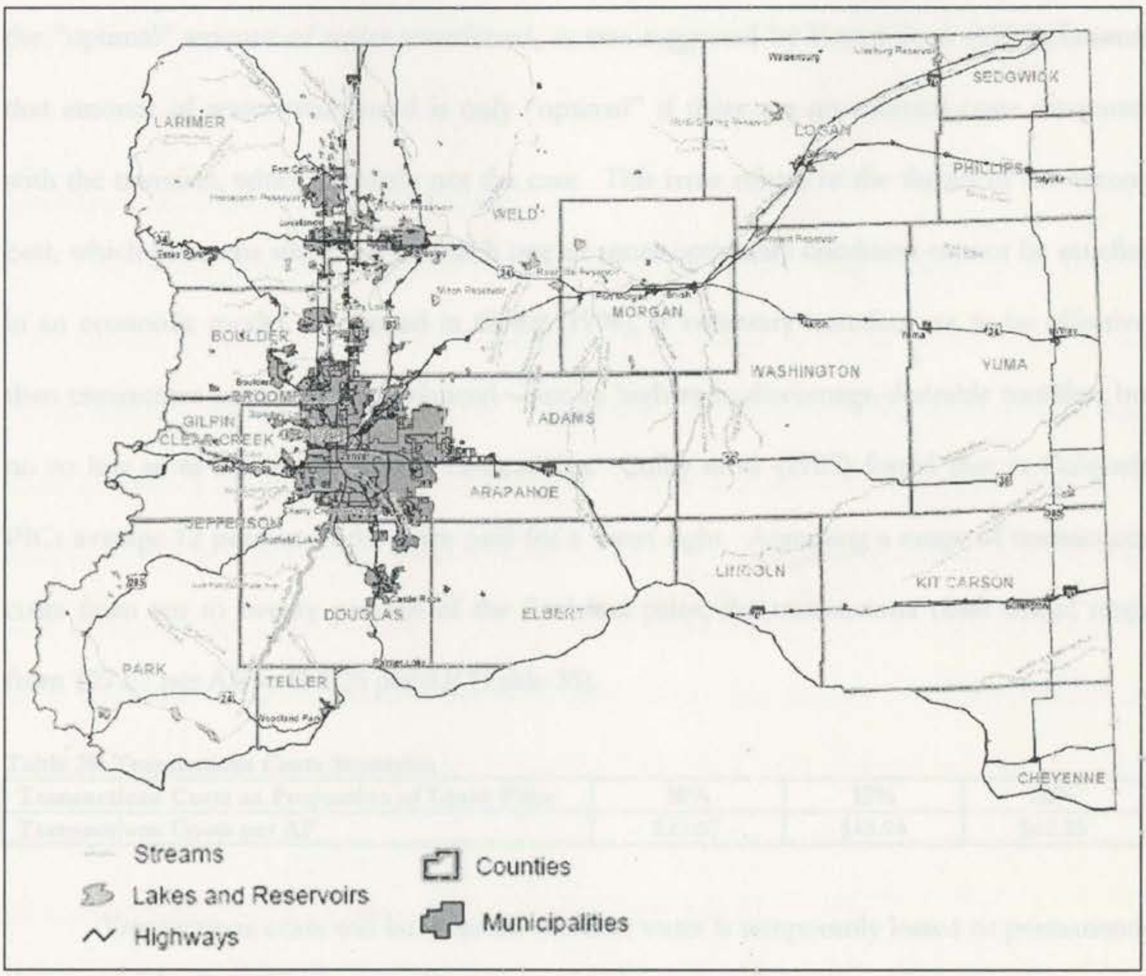

Figure 13: South Platte Basin (Colorado Water Conservation Board, 2004, Section 3)

Transactions Costs

Because transactions costs effectively increase the price of a water transfer, it has been suggested that transactions costs should be lowered to ease the transfer of water. However, policy-induced transactions costs (PICs) result from the political action of third-parties who are concerned about in-stream water use, environmental quality, and the economic impacts to rural communities. Thus, to the extent that PICs represent the third-party impacts of permanent water transfers, they should not be considered as preventing society from attaining the "optimal" amount of water transferred, as was suggested by Easter et al. (1998). because that amount of water transferred is only "optimal" if there are no external costs associated with the transfers, which is clearly not the case. This issue relates to the theory of the second best, which concerns situations in which one or more optimality condition cannot be satisfied in an economic model. As stated in Colby (1998), if voluntary transfers are to be effective, then transaction costs must be balanced-–not so high as to discourage desirable transfers but no so low as to allow unmitigated externalities. Colby et al. (1989) found that in Colorado PICs average 12 percent of the price paid for a water right. Assuming a range of transactions costs from ten to twenty percent of the final leas price, the transactions costs would range from $27.67 per AF to $62.25 per AF (Table 35).

Table 35: Transactions Costs Scenarios

Transactions Costs as Proportion of Lease Price	**10%**	**15%**	**20%**
Transactions Costs per AF	$27.67	$43.94	$62.25

Transactions costs will be incurred whether water is temporarily leased or permanently transferred. Whether the transactions costs are smaller or larger under a leasing scenario remains to be seen—a study of the full transaction costs of a change to an alternative water allocation mechanism has not been attempted (McCann and Easter, 2004). However, leased water may involve fewer storage requirements than purchased water and may thus represent a cost savings to municipalities. The South Metro Water Supply Authority (2007) estimated annual capital costs for surface water facilities in Colorado to range from $400 to $850 per AF for mid-term supplies and from $600 to $1,300 per AF for long-term supplies. Based on these figures, storage cost savings have the potential to outweigh the transactions costs of leasing.

Survey respondents state a willingness to lease water at a price that is within the bounds of current water transactions. It remains to be seen whether a sufficient amount of water would be made available to encourage leasing markets to evolve. This issue is addressed in the next subsection.

Quantities of Fallowed Land and Leased Water

Sixty-one percent of respondents said they would be willing to lease their water if compensated enough. In sum, the respondents were willing to fallow 33,352 acres, which would supply cities with roughly 50,000 additional AF of water annually, depending on how water courts evaluate historical consumptive use. Nearly 25 percent of respondents plan to sell their water rights, which would take an additional 8,562 acres out of irrigation and supply cities with approximately 12,800 additional AF of water. Thus, cities could be expected to receive up to 83,000 AF of water annually just from these survey respondents, which would fulfill 20 percent of South Platte cities' expected shortfall[19] by 2030. On average, respondents were willing to fallow 59 percent of their irrigated land, for an average 200 acres per farm. A more detailed illustration of these responses is provided by Figure 14.

[19] Cities in the basin have identified a shortfall of 409,700 AFY (Colorado Water Conservation Board, 2004).

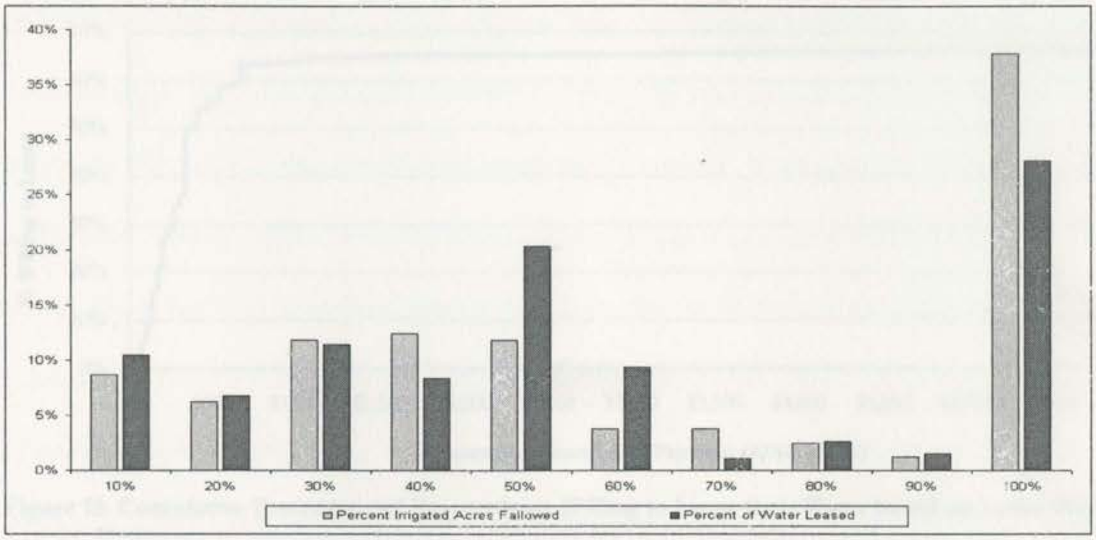

Figure 14: Percent of Irrigated Acres Fallowed and Water Supplies Committed to an Annual Lease

Respondents tend to cluster into two groups, one of which consists of those that are willing to commit all of their land and water to a lease. Leasing from these respondents may reduce transactions costs and help meet the necessary requirement of having sufficient water available for lease, but may do little to prevent the regional economic base from shrinking. The second cluster consists of those that are willing to commit half of their holdings or less to a leasing arrangement. Respondents in this cluster likely plan to stay in farming, which will help to avoid 'hot spot' problem of clustered areas taken out of irrigation; however, they could be problematic in reducing transactions costs for leasing arrangements since it may cost more to collect, treat and transport water from many small sources than a few large sources.

In line with economic theory, the higher the expected price for leased water, the greater the number of farmers who are willing to lease (Figure 15) and the more water is made available for lease (Figure 16).

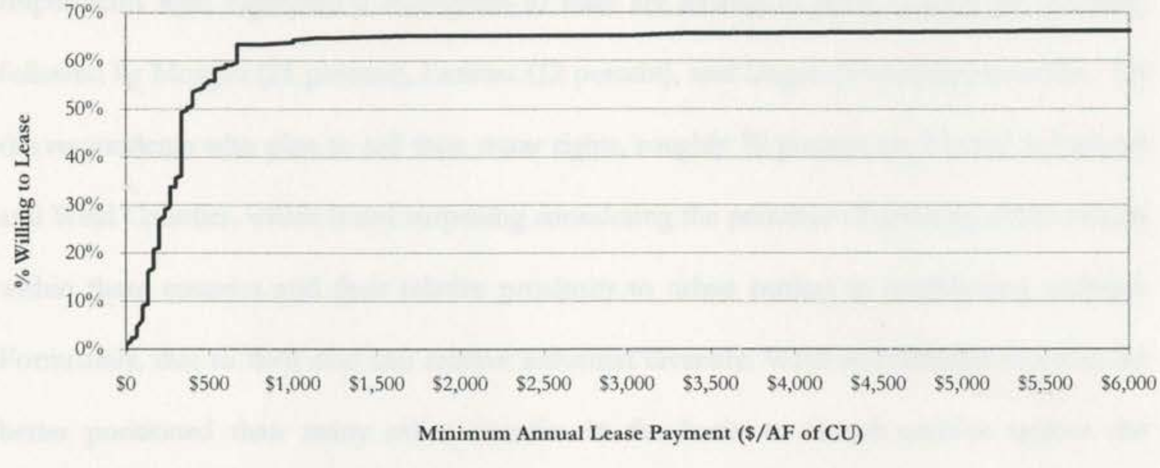

Figure 15: Cumulative Percentage of Respondents Willing to Lease their Water based on Lease Price

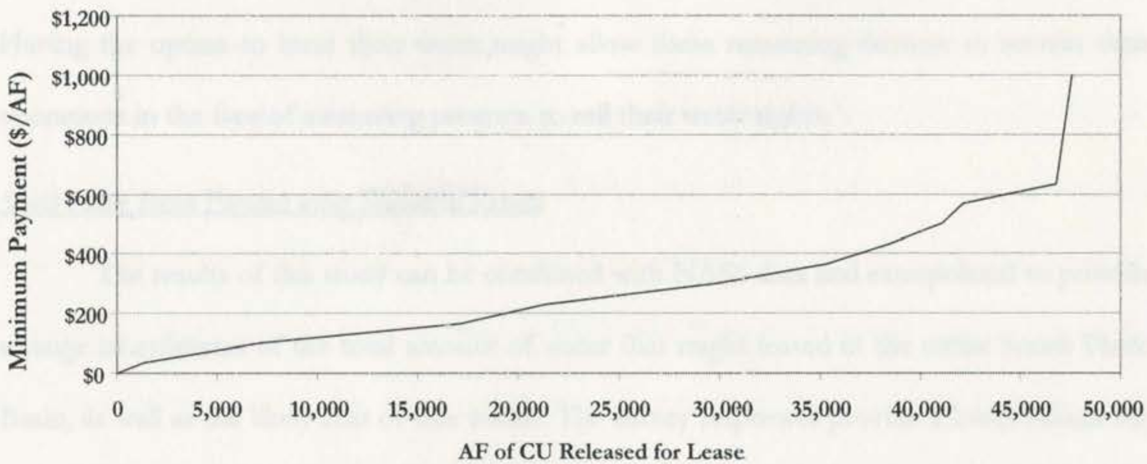

Figure 16: Respondents' Stated Annual Supply of Water for Lease

Location of Leased Water

It would be undesirable to have all leasers concentrated in one or two counties because this would leave little irrigated land in these counties, resulting in effects similar to those of permanent water transfers. On the other hand, some clustering is desirable so that transactions costs can be limited. The results of this study suggest that a lease program in the South Platte Basin could achieve such an intermediate level of clustering. Most of the respondents who expressed a willingness to lease are located in Weld County (40 percent), followed by Morgan (21 percent), Larimer (12 percent), and Logan (10 percent) counties. Of the respondents who plan to sell their water rights, roughly 70 percent are located in Larimer and Weld Counties, which is not surprising considering the presence of growing urban centers within these counties and their relative proximity to urban centers in neighboring counties. Fortunately, due to their size and relative industrial diversity, Weld and Larimer counties are better positioned than many other counties in the basin to absorb and/or replace the economic activity lost as a result of a water sale. Furthermore, as just discussed, there remain a number of farmers in these two counties who are willing to lease rather than sell their water. Having the option to lease their water might allow these remaining farmers to sustain their operations in the face of increasing pressure to sell their water rights.

South Platte Basin Forecast using Statistical Results

The results of this study can be combined with NASS data and extrapolated to provide a range of estimates of the total amount of water that might leased in the entire South Platte Basin, as well as the likely cost of this water. The survey responses provide a lower bound for this range, under the assumption that no additional farmers in the South Platte Basin would enter a fallow-lease program. A total of 33,000 acres would be fallowed, releasing 49,500 AF and fulfilling 12 percent of South Platte municipalities' expected shortfall. If each farmer who was willing to lease was compensated at their stated minimum WTA amount, these 49,500 AF would cost $15 million.

It is more likely, however, that some additional farmers who did not fill out the survey would also be willing to enter into a fallow-lease arrangement. In order to project the survey results out to the entire South Platte Basin, it is necessary to make some assumptions about the

2,026 farmers who did not fill out the survey[20]. While the simplest option would be to assume that non-respondents are identical, on average, to respondents, it is more likely that farmers who took the time to fill out and return the survey have stronger opinions about the future of farms and agricultural communities in Colorado, and may be more willing than the average South Platte farmer to enter into a lease agreement. This makes it difficult to project the survey results out to the entire South Platte Basin; nevertheless, a conservative range of estimates will be useful for cities as they plan for their future water supplies and for rural community leaders as they consider alternative economic development plans.

In their analysis of a conceptual fallow-lease program in Colorado's Arkansas Basin, HDR Engineering assumed that 65 percent of all available irrigated acres would be included in the program—what they consider to be a conservative assumption given participation rates of nearly 100 percent experienced in the Aurora-High Line and PVID programs. However, just sixty percent of the respondents to this survey were willing to lease their water, and applying this same participation rate to all irrigators in the South Platte Basin would almost certainly be an overestimate. Under the more conservative assumption that 25 to 50 percent of all remaining irrigators in the South Platte Basin would be willing to lease their water, an additional 507 to 1,013 farmers would join the program.

To determine how many acres this would add to the program, it is assumed that each of these farmers owns 980 irrigated acres—the average irrigated acreage per farm in the South Platte Basin according Colorado Agricultural Statistics (2008). Respondents to this survey were willing to fallow an average of 60 percent of their land as part of a lease program. Assuming a lower figure of 50 percent for non-responding irrigators results in approximately

[20] According to the 2002 Agriculture Census, there are 2,355 farms with at least 50 irrigated acres in the Basin.

250,000 to 500,000 acres available for fallowing. HDR Engineering assumed a fallowing rate of 25 percent, which is the same fallowing rate called for under the Super Ditch plan (Ozzello, 2009). Making the same assumption here, 94,000 to 188,000 AF of water would be released for lease annually, fulfilling an additional 24 to 45 percent of South Platte municipalities' expected water shortage.

To estimate the cost of this additional leased water, the estimated amounts of fallowed land were separated according to the proportion of South Platte farms in each farm size category (Table 36). The weighted median WTA amounts corresponding to each of these farm size categories was then applied to these fallowed acreages. Assuming a 25 percent participation rate, the total cost amounts to roughly $19.3 million. Assuming a 50 percent participation rate, the total cost amounts to roughly $96.3 million.

Table 36: Two Water Lease Scenarios in the South Platte Basin

Farm Size (acres)	50-179	180-499	500-999	1,000 or more
Proportion of SP Basin Farmers	33%	22%	14%	31%
Acres Fallowed by Non-Respondents				
25% Participation Rate	16,500	11,000	7,000	15,500
50% Participation Rate	82,500	55,000	35,000	77,500

Another seven percent of respondents plan to sell their water rights, which would result in the permanent dry-up of roughly 8,600 acres, representing eight percent of respondents' total irrigated land. Extending this eight percent selling rate out to the remaining irrigated acres in the South Platte Basin would result in the fallowing of an additional 40,240 acres as water rights are sold to municipalities. This would free up an additional 60,360 AF of water annually and meet an additional 15 percent of cities' stated water needs.

Characteristics of Respondents Who Are Willing to Lease

Identifying the characteristics that are shared by farmers who expressed a willingness to lease will help to identify potential incentives and barriers to leasing. Table 37 displays the results of the binary logit regressing "willingness to lease" on farm and farmer characteristics.

Table 37: Farm and Farmer Characteristics that Influence Willingness to Lease

Dependent Variable: Willingness to Lease			
Explanatory Variable	**Coefficient**	**Standard Error†**	**Probability**
Constant	-10.43	2.38	0.0000
Beneficial for rural communities**	1.23	0.51	0.0168
Debt*	-0.98	0.56	0.0765
Education level	-0.06	0.16	0.6863
Experience**	0.18	0.06	0.0029
Experience^2**	-0.0023	0.0008	0.0033
% Ground Water**	-0.02	0.01	0.0461
Irrigated Acres	0.0004	0.0005	0.5107
Source of revenue for farmers**	1.75	0.76	0.0204
Meet Colorado's water needs**	0.49	0.21	0.0214
Plans to sell water rights	0.60	0.98	0.5420
Plans to upgrade	0.57	0.48	0.2327
Reduce financial risk of my farm**	0.76	0.24	0.0015
Second Job	0.11	0.43	0.7948
Urban Proximity**	-1.82	0.58	0.0017
Well Shut-Down	0.80	0.56	0.1532
Work with municipalities**	0.44	0.22	0.0462
Work with other organizations**	0.57	0.28	0.0403

McFadden R-squared: 0.3948	Log-likelihood: -67.51664
S.E. of regression: 0.3869	Restricted log likelihood: -111.56
Sum squared residuals: 22.16	Correct Classifications: 80.7%

†QML (Huber/White) standard errors and covariances
*Statistically significant, $\rho<0.10$
**Statistically significant, $\rho<0.05$

The most important driving factors in the decision to lease were the beliefs that leases can be a source of revenue for farmers and that leases are beneficial to rural communities. The belief that leases will reduce the financial risk of farm operations was also found to have a statistically significant positive effect on willingness to lease. These results are not surprising—farmers who have a favorable view of leases in terms of their effect on the farmer's own operation, rural communities, and the state as a whole should be expected to be more likely to enter into a lease agreement. Farmers who are willing to negotiate with municipalities and/or with other organizations are more likely to lease their water. It is thus encouraging that the majority of survey respondents indicated a willingness to work with municipalities and/or other organizations to negotiate lease agreements. As expected, the results indicate that willingness to lease increases at a decreasing rate with farming experience.

Variables that were found to have a statistically significant negative impact on willingness to lease include percent ground water use and proximity to urban centers. Because ground water cannot be leased, it makes sense that having a higher proportion of one's water portfolio coming from ground water would negatively influence the decision to enter into a lease agreement. Proximity to urban centers suggests increased pressure for urban development and thus a greater chance of selling the land and accompanying water rights.

A farmer's plans to sell his or her water rights has no apparent effect on his or her willingness to lease. Farmers who are planning to sell their water rights may have already made the decision to exit the business and are not interested in leasing. On the other hand, farmers who are planning to sell their water rights may just be looking for the best way to benefit from their water right holdings and may view leases as an acceptable alternative way to do so.

<u>*Barriers to Leasing*</u>

Some of the barriers to leasing can be identified by examining the characteristics of those farmers who are *not* willing to lease their water. To this end, a logit model was used to regress "unwillingness to lease[21]" on the same set of explanatory variables (Table 38). The survey responses appear to do a better job of explaining an *un*willingness to lease—this model

[21] "Unwillingness to lease" was defined as a response of *strongly disagree* or *disagree* to the same lease statement.

has larger McFadden R^2 and log-likelihood values, and does a slightly better job of correctly predicting responses, correctly predicting 88.0 percent of responses (95.5 percent of y =1 responses and 57.6 percent of y =0 responses).

Table 38: Barriers to Water Leasing

Dependent Variable: Unwillingness to Lease			
Explanatory Variable	**Coefficient**	**Standard Error†**	**Probability**
Constant	4.88	1.86	0.0087
Beneficial for rural communities	-0.48	0.74	0.5193
Debt	0.65	0.70	0.3523
Education level	0.26	0.19	0.1581
Experience	0.02	0.08	0.8101
Experience^2	0.00	0.00	0.5953
% Ground Water**	0.02	0.01	0.0192
Irrigated Acres*	0.00	0.00	0.1074
Source of revenue for farmers	-0.66	0.79	0.3983
Meet Colorado's future water** needs	-0.88	0.24	0.0002
Plans to sell water rights	0.09	1.18	0.9377
Plans to upgrade	-0.78	0.60	0.1911
Reduce financial risk of my farm**	-1.06	0.30	0.0004
Second Job	0.12	0.58	0.8365
Urban Proximity**	2.43	0.94	0.0094
Well Shut-Down**	-1.77	0.76	0.0206
Work with municipalities	-0.49	0.32	0.1238
Work with other organizations	-0.25	0.28	0.3770
McFadden R-squared: 0.4474	Log-likelihood: -45.75		
S.E. of regression: 0.3080	Restricted log likelihood: -82.79		
Sum squared residuals: 14.04	Correct classifications: 88.0%		

†QML (Huber/White) standard errors and covariances
*Statistically significant, ϱ<0.10
**Statistically significant, ϱ<0.05

The two main barriers to leasing identified in this study are percent ground water use and proximity to an urban center. Intuitively, the beliefs that water leases will help meet Colorado's future water needs and that water leases would reduce the financial risk of the respondent's farm were both found to reduce unwillingness to lease. Thus, one way to increase farmer participation would be to include in the lease agreement stipulations that ensure greater financial stability of farm operations. While owning a greater number of irrigated acres did not appear to increase willingness to lease, it does appear to reduce resistance to the idea. While having one's well shut down did not appear increase farmers' willingness to lease, it does appear to reduce farmers' *un*willingness to lease. Farmers who had their well(s) shut down may have less confidence in the farming business and may be more concerned about having their pumping curtailed again, making them less opposed to the idea of water leases.

An important finding is that while there is some (weak) evidence that an improved relationship between municipalities and farmers would reduce resistance to leasing, it is not necessary that a farmer be willing to work directly with a municipality in order for that farmer to be willing to lease his or her water to the municipality. Many farmers have long-standing feelings of mistrust and general negativity toward municipalities as a result of previous 'buy and dry' activity (as evidenced by the minority of respondents of this survey who indicated a willingness to work directly with municipalities, as discussed previously); thus, it is highly encouraging that an unwillingness to work with municipalities does not act as a barrier to leasing. Because the majority of survey respondents indicated that they would be willing to work with other organizations to negotiate lease agreement, and because this is associated with a greater willingness to lease, it is quite possible that a water lease market could arise despite any animosity between farmers and municipalities.

Interestingly, although the largest proportion of willing leasers were located in Weld County, the largest proportion of respondents who were *not* willing to lease (57 percent) were also located in Weld County. The next greatest proportion of non-leasers came from Larimer County (12 percent). These two counties are among the most urban counties in the South Platte Basin, and each encompasses portions of the I-25 corridor, a region that is experiencing rapid development. This would seem to suggest that these respondents may be experiencing greater development pressure and thus may have plans to sell their water rights. Indeed, one-third of the non-leasers from Larimer County expressed having plans to sell their water rights. However, none of the non-leasers from Weld County had plans to sell their water rights; thus, the high number of non-leasers in this Weld County may have more to do with the fact that the majority of all responses came from this County.

This section has examined the factors that influence the decision to lease. When considering those farmers who are willing to lease, it is instructive to examine the factors that influence their decisions regarding the number of acres to fallow and the minimum payment to request. The next sections address these questions by considering just the 164 farmers who expressed a willingness to lease.

Determinants of Number of Acres Fallowed

Identifying the factors that influence the number of acres fallowed by those farmers who were willing to lease will provide further insight into the leasing decision and will provide additional precision when predicting the number of acre-feet that would likely be supplied basin-wide. OLS was used to regress the number of acres that respondents would fallow as part of a lease agreement on a number of farm and farmer characteristics. In addition to a number of explanatory variables that were used in the previous regression analyses, this regression also included a dummy variable indicating that a respondent listed a WTA amount of $500 or greater, under the premise that respondents who are expecting to receive a higher per-acre price would likely be willing to fallow a larger number of acres. This regression also included a dummy variable indicating that a farmer practice no tillage or direct tillage methods on their irrigated acres. Farmers who use no-tillage or direct tillage methods tend to grow more wheat, which is a less water-intensive crop and would thus require a greater number of acres to be fallowed to release a given amount of water for lease. This variable is thus expected to have a positive effect on the number of acres fallowed. The results of the regression are displayed in Table 39.

Table 39: Some Determinants of the Acreage Fallowed as Part of a Lease Agreement

Dependent Variable: Number of acres fallowed			
Variable	**Coefficient**	**Std. Error†**	**Probability**
C	26.23	132.0556	0.8429
Debt	27.78	31.2749	0.3762
Age**	-3.65	1.42355	0.0116
Prefer One Large Payment**	-68.51	29.3424	0.0213
WTA ≥ $500**	84.73	37.2605	0.0248
No Till**	117.18	54.3161	0.0330
Work with municipalities**	37.11	13.5636	0.0072
Source of revenue for farmers**	77.82	36.0749	0.0330
Reduce financial risk of my farm**	-48.71	23.5098	0.0405
Irrigated acres**	0.3718	0.0861	0.0000
% Ground Water	0.6834	0.4469	0.1290
Adjusted R-squared: 0.5761	S.D. dependent variable: 319.71		
S.E. of regression: 208.15	F-statistic: 18.13 (probability = 0.0000)		
Sum squared residuals: 5,025,710	Log likelihood: -852.41		

† White heterskedasticity-consistent standard errors and covariance
**Statistically significant, ϱ<0.05

Farmers who own more irrigated acres were willing to fallow a greater number of acres, which is intuitive—these farmers have more acres that could potentially be fallowed. Farmers who believe that leases can be a source of revenue and farmers who are willing to work with a municipality were also willing to fallow a larger number of acres. In line with economic theory, the higher the expected payment per acre, the more acres a farmer would fallow. Also as expected, farmers who used no-tillage or direct tillage methods were also willing to fallow more acres. Interestingly, conventional tillage and reduced tillage were the tillage methods practiced most often by respondents.

Farmers who prefer one large lease payment may not view leases as a long-term strategy, which may explain why they were not willing to fallow as many acres. Somewhat unexpectedly, farmers who believe that leases can reduce the financial risk of their farm were not willing to fallow as many acres. Age was a more important factor than experience in this decision, with fallowed acreage declining with age.

Determinants of the Willingness to Accept Amount

It is also instructive to determine the factors that affect the payment desired by farmers for leasing their water. To this end, OLS was used to regress farmers' stated WTA amount for leasing water on a number of farm, farmer, and lease agreement characteristics (Table 40).

Table 40: Some Determinants of Farmers' Stated WTA Amount

Dependent Variable: Minimum Lease Payment			
Variable	**Coefficient**	**Std. Error**	**Prob.**
C	-2453.76	1763.31	0.1707
Debt	-404.54	411.38	0.3306
Beneficial for rural communities	418.30	275.61	0.1359
Ditch company**	15.22	6.36	0.0208
Age*	38.37	19.46	0.0546
Large Payment	-340.66	244.26	0.1698
Long-term lease	-15.87	137.59	0.9087
No till	-467.94	373.70	0.2168
% Hay	699.05	629.56	0.2726
Work with municipalities	205.31	143.74	0.1599
Work with other organizations**	742.68	336.33	0.0323
Annual gross sales	131.06	86.12	0.1349
Acres fallowed as part of a lease agreement	-0.20	0.36	0.5919
Well shut-down**	154.04	72.21	0.0383
Leases will help meet CO's future water needs**	-1284.24	425.80	0.0042
Plan to upgrade	-28.07	290.56	0.9235
Center pivot	5.62	3.70	0.1357
% Ground Water*	10.16	5.84	0.0884
Adjusted R-squared: 0.4471	S.D. dependent variable: 1545.55		
S.E. of regression: 1149.23	Log likelihood: -531.24		
Sum squared residuals: 60,753,347	F-statistic: 4.00 (probability = 0.0001)		

† White Heteroskedasticity-Consistent Standard Errors & Covariance
**Statistically significant, $\varrho<0.05$
*Statistically significant, $\varrho<0.10$

Farmers who had their well pumping curtailed demand a higher payment per acre. These farmers may feel slighted by the system (and by the burgeoning water demands that were partly to blame for the curtailment), and thus feel entitled to a higher price for their water. Farmers who receive a greater proportion of their water from groundwater wells also demand a higher payment per acre. This may be a response ro the fact that these farmers have proportionately less water that can be leased. Farmers whose water is supplied by a ditch company also demand a higher payment per acre. Farmers who are part of a coalition may feel that there will be power in numbers when it comes to negotiating lease prices with municipalities and thus may have greater courage to request a higher payment. An important finding is that these farmers do not require a higher payment in order to sign a long-term lease.

Farmers who believe that leases will meet Colorado's future water needs demand a lower lease payment. This result could signal a sense of altruism towards fellow Coloradans. Alternatively, it could signal a sense of realism—if a farmer believes that leases truly are going to play a large role in supplying future needs, there may be less hypothetical bias, which tends to inflate stated WTA amounts.

Conclusions

This study focused on the stated preferences of irrigators in Colorado's South Platte Basin. Respondents' preferences provide some direction for the budding market for water leases by helping in the design of lease agreements and the targeting of potential leasers. Respondents generally have a favorable view of the impact that leases will have for farmers and rural communities, and many are willing to lease their water at reasonable prices. Based on these responses and some assumptions regarding other irrigators in the Basin, leases have the potential to serve as a substitute for permanent water transfers in some cases and fulfill a portion of municipalities' needs.

One of the primary reasons for pursuing water leases in place of permanent water transfers is to reduce the negative economic impacts experienced by the communities-of-origin. While leases will are expected to result in fewer negative economic impacts than permanent transfers, a number of factors will influence the regional impact of a fallow-lease program. These include:

Relative location of the rotationally fallowed land: If the fallowed land is concentrated in one area, the economic impact will be greater than if the acres are distributed more evenly through the entire region. There is evidence that a moderate amount of clustering would occur if a fallow-lease program were instituted in the South Platte Basin.

Structure of the lease payments: It has been suggested that a payment approach involving a large up-front payment approach may not have as large a regional benefit as a payment approach involving regular payments over time. Fortunately, survey respondents indicated that they would prefer to receive regular payments over time as opposed to one large up-front payment.

Ownership of the participating cropland: If the land is owner-operated, a greater proportion of lease proceeds will likely be re-invested in the operation, to the economic benefit of the region. The 2002 Census of Agriculture shows that 53 percent of harvested cropland in the study area is owner-operated and that 50 percent of principal operators live on-farm.

Magnitude of the lease payments: The higher the price received for the leased water, the greater the economic activity generated by the leases. This in turn will depend on the seniority of the water rights. Just over 50 percent of willing leasers agreed with the notion of leasing their senior water rights and keeping their junior rights if suitably compensated.

Quality of the fallowed land: Fallowing marginal lands would mitigate production losses because such losses would be proportionately less than the acreage reduction. This is an aspect of fallow-leasing programs that was not addressed in this study.

Diversity and economic health of the regional economy: As observed by Howe and Goemans (2003), a more vibrant economy can better absorb the adverse impacts of water transfers due to alternative employment and investment opportunities. Fortunately, Weld County, where most of fallowing is expected to occur, is a relatively large and diverse economy which should allow it to replace much of the economic activity lost due to fallowing.

Where the lease revenues are spent. The lease revenues will do little to support the local economy if they are largely spent or invested non-locally. Fortunately, 83 percent of those who stated a willingness to lease said that they purchased the majority of their inputs locally—evidence that leases would protect regional economic activity by maintaining this positive multiplier effect of irrigated agriculture.

A logit model was constructed based on survey responses to determine some of the factors that influence farmers' decisions to lease their water rights to municipalities. Then, focusing on those farmers who indicated a willingness to lease, OLS regression was used to determine the factors influencing the number of acres fallowed as part of a lease agreement and the payment per acre required for doing so.

While the only demographic characteristic that was found to significantly influence the decision to lease was farming experience, the beliefs of the farmer were very influential: the beliefs that leases are beneficial for rural communities, that leases can be a source of revenue for farmers, and that leases can reduce the financial risk of farm operations all had a positive effect on the lease decision. Education did not have a significant effect on the decision to lease, nor did having plans to upgrade the irrigation system or to sell the water rights. Unlike Zhou et al. (2008), who found off-farm occupation to have a significant negative effect on the adoption of water-saving technologies, off-farm occupation was not found to significantly influence the decision to lease. With respect to characteristics of the farm, large farms had higher lease probabilities, similar to the findings of Zhou et al. (2008). Zhou et al. (2008) found low reliability of irrigation water supply to increase adoption of water-saving technologies. Similar results are found here—farmers who had had their wells shut down (indicative of low reliability of water supply) were less opposed to water leasing.

Notes, Limitations, and Future Opportunities

Dillman (2007, p. 206) lists f our factors must be taken into consideration when determining how large a sample size is needed in order to make inferences about the population: the acceptable level of sampling error; the chosen level of confidence in the estimates made from the sample; the size of the population from which the sample is drawn; and how varied the population is with respect to the characteristic of interest. Dillman (2007, p. 206) also provides a formula incorporating these four factors to calculate the necessary sample size for a given level of precision. Given a population size of 2,335 farms with at least 50 irrigated acres in Colorado's South Platte Basin and assuming a 50/50 split in willingness-to-lease responses, a sample size of 330 is required for a sampling error of five percent. With 319 surveys completed, the sample size achieved here very nearly meets this requirement. Nonetheless, because the consistency and asymptotic efficiency properties of ML rely on large sample sizes, the results of the logit analyses performed here should be interpreted with caution. Analysis with a larger sample would be useful for comparing results and providing additional insight.

The inclusion of more detailed lease data would also prove useful, and will become more feasible as water leases become more common. For instance, the payment that farmers require in exchange for leasing their water and the payment municipalities are willing to make for that water will vary according to a variety of factors, one of which is the level of priority of the water right being leased, since in a dry year a relatively junior right may not be satisfied in its entirety, if at all. However, as noted by McCrea and Niemi, 2007), even information about hypothetical future transactions can be useful in lower the costs of negotiating an agreement by a leaser and lessee.

A leasing market may prove to be too "thin" if the water made available by farmers is of relatively junior priority, and municipal water providers instead seek scarcer, senior water rights (Colby, 1998). Fortunately, just over half of all willing leasers agreed to lease their senior water rights while keeping their junior rights, if suitably compensated. Other challenges related to water leasing that were not addressed here include verifying the actual use of water and monitoring its quality after it is transferred (Doherty, 2010). Leases will require adjudication of changes in the location and use of the water (Nichols, 2010).

CHAPTER 5: CONCLUDING REMARKS

Paraphrasing Colorado Supreme Court Justice Greg Hobbs (2007), "Rather than developing a water resource, we are now learning how to share an already developed resource." The panel regression in Chapter 2 provided an alternative way to estimate the economy-wide impacts of reduced irrigated agriculture. By using an econometric approach, the study accounted for forward linkages and adaptation over time and allowed several opportunities for testing for structural breaks in the relationship between irrigated land and economic health. Use of a large study area provided enough variation to detect the individual effect of irrigated agriculture while controlling for a number of other factors and allowing some general conclusions to be drawn. The results provided some evidence that irrigated agriculture contributes positively to population, sales, industrial diversity, and employment in rural agricultural counties, particularly when there are more than 10,000 acres of irrigated land.

The results reported in Chapter 3 provide evidence that households are willing to pay for water supply initiatives, particularly those aimed at reservoir construction, keeping irrigated farms in production, and reusing household water. There is also evidence that water knowledge increases willingness to pay. The surveys in Chapters 3 and 4 indicate that some of the necessary conditions for a working water lease market would be met in Colorado's South Platte Basin: urban households do not prefer to permanently transfer water out of agriculture and a significant number of farmers willing to lease their water at prices that are within the bounds of previous transactions. The task remains to further investigate the legal requirements and transactions costs associated with such a lease market.

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APPENDIX A: DATA SOURCES AND CORRELATION

Table A1 lists the sources of data used for the study in Chapter 2, while Tables A2 and A3 show the coefficients of correlation among explanatory variables. Please see the References section for more information about accessing these data sources.

Table A1: Data Description, Year, and Source

Variable	Data Source
Population	USA Counties
Unemployment	Bureau of Labor Statistics
Value of Sales	USA Counties
Shannon-Weaver Index	IMPLAN, USDA Forest Service
Highway Spending per Acre	USA Counties
Non-farm Establishments	USA Counties
Lagged Population	USA Counties
Lagged Unemployment Rate	USA Counties
% Healthcare Establishments	USA Counties
% Female Workers	USA Counties
% of Population Caucasian	USA Counties
% of Population over 60	USA Counties
% of Population with Bachelor's Degree or Higher	USA Counties
% of Households headed by a Married Couple	USA Counties
Median Income	USA Counties
Violent Crimes	USA Counties
USDA ERS Urban-Rural Continuum Code	USDA-ERS
Tax Revenue per Capita	USA Counties
USDA-ERS Natural Amenity Rank	USDA-ERS
USDA Farm Production Region	USDA, 1999
Average Farm Size	NASS
Irrigated Land	NASS
Drought	National Oceanic and Atmospheric Administration

Table A2: Correlation Coefficients for Some Study Variables

	Drought	Healthcare	Hwy Spending	Irrigated Land	Over 60	Bachelor Degree	Nat. Amenity	Married	Caucasian
Healthcare	0.05	1.00							
Hwy Spending	0.29	0.18	1.00						
Irrigated Land	-0.08	-0.01	0.03	1.00					
% over 60	0.24	0.15	-0.08	-0.24	1.00				
Bachelor Degree	-0.03	0.31	0.18	0.06	-0.32	1.00			
Nat. Amenity	-0.26	-0.01	-0.07	0.01	-0.41	0.31	1.00		
% Married	-0.10	-0.34	-0.19	0.21	0.03	-0.25	-0.12	1.00	
% Caucasian	-0.09	0.10	0.01	0.17	0.27	0.17	-0.09	0.41	1.00
% Female	0.24	0.42	0.30	-0.11	0.09	0.21	0.00	-0.48	-0.21
Ruralness	0.14	-0.11	-0.26	-0.05	0.29	0.06	-0.12	0.18	0.16
S-W Index	-0.04	0.46	0.26	0.09	-0.03	0.08	0.10	-0.26	-0.05
Tax Revenue	0.03	-0.09	0.13	0.05	-0.07	0.20	-0.01	0.18	0.23
Non-farm Estabs	-0.08	0.38	0.46	0.11	-0.31	0.39	0.24	-0.33	-0.05
Northern Plains	0.65	0.13	0.21	0.00	0.39	-0.02	**-0.51**	0.06	0.13
Southern Plains	-0.10	-0.17	0.00	-0.19	-0.02	-0.28	0.00	-0.02	-0.19
Avg. Farm Size	-0.12	-0.13	-0.39	-0.04	-0.17	0.06	0.03	0.09	-0.02
Early Population	-0.05	0.27	0.41	0.08	-0.30	0.06	0.21	-0.23	-0.24
Median Income	0.05	-0.18	0.28	0.26	-0.34	0.45	0.13	0.19	0.31

Table A3: Correlation Coefficients for Additional Study Variables

	Female	Ruralness	S-W Index	Tax Revenue	Non-farm Estabs	NP	SP	Avg Farm Size	Early Pop
Ruralness	-0.25	1.00							
S-W Index	0.47	-0.48	1.00						
Tax Revenue	-0.19	0.20	-0.32	1.00					
Non-farm Estabs	0.36	**-0.52**	**0.60**	-0.12	1.00				
NP	0.16	0.31	-0.12	0.07	-0.18	1.00			
SP	-0.13	-0.36	0.07	-0.02	0.04	**-0.55**	1.00		
Avg. Farm Size	-0.19	0.16	-0.24	0.19	-0.27	-0.11	-0.03	1.00	
Early Population	0.30	**-0.67**	**0.57**	-0.25	**0.84**	-0.29	0.26	-0.30	1.00
Median Income	-0.03	-0.06	0.11	0.31	0.31	0.13	-0.33	-0.13	0.10

There is moderate correlation between the S-W index and the number of non-farm establishments, which is not wholly unexpected—a larger number of establishments may spur the co-location of input suppliers and service establishments. However, because each of these variables measures something different and essential to this study—economic diversity and size, respectively, and because both variables are individually statistically significant in nearly all estimated models, there is great risk of omitted variable bias if either variable is omitted; thus, neither variable is omitted from the models here. There is also moderate negative correlation between the farm production region dummy variables, which is expected—if a county is not located in the Northern Plains (NP) region, then it must be located in either the Southern Plains (SP) or Mountain region. This is a common phenomenon with dummy variables and is not of great concern. Furthermore, the issue becomes moot when the FE estimator is used. There is also moderate negative correlation between the Northern Plains dummy variable and the natural amenity rank, which suggests that most counties in the Northern Plains region have relatively low natural amenity ranks. Nonetheless, because the farm production regions are based on many factors in addition to climate, it contains unique information that is also important in explaining rural economic health. And again, the issue becomes moot when the FE estimator is used.

APPENDIX B: A SUMMARY OF RESULTS FROM THE INTERNET SURVEY OF WESTERN HOUSEHOLDS

Exploratory Analysis: Correlation among Explanatory Variables

As discussed in the previous Chapter 2, the coefficients of correlation between variables can provide information about the possible presence of heteroskedasticity in a regression. Examining correlations between variables is also useful for forming some insight into the nature of the respondents' preferences and the relationships between these preferences and other characteristics of the respondent. The coefficients of correlation among the explanatory variables used in Chapter 3 are displayed in Tables B1 and B2.

Table B1: Coefficients of Correlation between Explanatory Variables

	WT P Yes	Homeowne r	Caucasia n	Income	Propose d Fee	City	Enoug h Water	Conservatio n Concerned	Voluntary Restrict	Water Knowledge	Regional Planning Needed
Homeowner	-0.05										
Caucasian	0.04	0.09									
Income	0.10	0.32	0.01								
Proposed Fee	-0.18	-0.01	-0.01	-0.01							
City	0.03	-0.02	-0.10	0.05	0.03						
Enough Water	-0.15	-0.05	-0.07	-0.04	-0.02	0.02					
Conservation Concerned	0.17	0.02	0.00	-0.02	0.03	-0.02	-0.24				
Voluntary Restrict	-0.16	0.01	0.03	-0.05	-0.01	-0.01	0.21	-0.17			
Water Knowledge	0.08	0.05	0.02	0.06	0.02	-0.05	-0.09	0.29	-0.02		
Regional Planning Needed	0.21	0.04	0.03	0.04	0.02	-0.01	-0.27	0.34	-0.13	**0.20**	
Limit Growth	0.05	0.06	0.05	0.01	0.02	0.00	-0.17	0.24	-0.09	0.16	**0.29**
Public Money	0.18	0.01	0.00	0.00	0.04	-0.01	-0.07	0.18	-0.04	0.10	**0.32**
Current Management	-0.12	-0.01	-0.07	0.02	-0.01	0.03	0.40	-0.27	0.21	-0.15	**-0.24**
Policymakers Understand	0.00	-0.07	-0.12	-0.01	0.01	0.06	0.24	-0.12	0.02	-0.11	-0.11
Do Nothing	-0.14	-0.04	-0.07	0.02	0.00	0.05	0.24	-0.18	0.08	-0.09	**-0.32**
Federal Subsidies	-0.07	-0.05	-0.05	-0.09	-0.02	0.01	0.06	-0.05	0.05	-0.04	-0.04
Age	-0.01	0.26	0.17	0.02	0.01	-0.08	-0.10	0.13	0.10	0.10	0.15
New Housing	-0.03	0.07	0.04	0.07	0.00	-0.02	-0.04	0.04	-0.01	0.05	0.02
Economy over Environment	-0.15	0.00	-0.05	0.01	-0.01	0.00	0.25	-0.24	0.21	-0.07	-0.24
Male	-0.01	0.02	-0.01	0.06	0.01	0.02	0.01	-0.07	0.04	0.14	-0.01

Table B2: Additional Coefficients of Correlation between Explanatory Variables

	Limit Growth	Public Money	Current Manageme nt	Policymakers Understand	Do Nothing	Federal Subsidies	Age	New Housing	Economy over Environment
Current Management	0.11	-0.08							
Policymakers Understand	-0.20	0.01	**0.52**						
Do Nothing	-0.14	-0.15	0.27	0.21					
Federal Subsidies	-0.12	0.02	0.02	-0.01	0.00				
Age	-0.10	0.07	-0.11	-0.20	-0.07	-0.07			
New Housing	0.09	-0.05	-0.07	-0.07	0.01	-0.22	0.10		
Economy over Environment	0.19	-0.07	0.26	0.15	0.19	0.02	0.02	-0.01	
Income	-0.12	0.00	0.01	0.00	0.01	-0.08	0.02	0.01	0.08
Male	0.01	-0.04	0.02	-0.03	0.08	-0.07	0.18	-0.03	0.08

As can be seen in Table B1, individuals who are satisfied with the way water resources are currently managed tend to also think that policymakers understand their priorities. While it is not surprising that these two variables are positively correlated, they each provide distinct information and were found to have opposing effects on the WTP decision.

Individuals who think that regional land use and water planning is needed to manage water scarcity tend to also think that the growth of cities should be limited and that public money should be used to develop new water resources. Interestingly, these individuals also tend *not* to be satisfied with current water management and to *disagree* with the notion that cities should not be required to do anything to compensate rural communities if water is taken from rural areas and given to cities.

Interestingly, water knowledge is positively correlated with the notion that regional land use and water planning is needed to manage water scarcity, but negatively correlated with the notion that the best way to ensure sufficient water for the future is through government regulation. In general then, individuals who feel relatively well-informed about water management in the west tend to realize that regional land use and water planning is needed, but do not think that government regulation is not the best way to implement such plans.

The correlation among variables provides insight into the relationship between the variables, but does not control for the contemporaneous impact of all variables on one another. Regressions analysis allows the analyst to better isolate the effects of particular variables by controlling for the effects of other variables. The next sections summarize respondent demographics and survey responses.

Demographics

The majority of respondents were female, Caucasian, and somewhat older than the general population (Table B3). Respondents' median income was somewhat below that of all western residents, and a slightly greater proportion of respondents owned their place of residence (Table B3). Respondents came from all 17 states in the study area (Table B4).

Table B3: Reported Age of Respondents

	Percent Male	Percent Caucasian	Median Age	Median Income	Percent Homeowners
Sample	27%	88.9%	51	Between $25,000 and $49,000**	68.6%
Western U.S.*	51.5%	82.1%	35	$49,059	62.6%

*Source: USA Counties

**Respondents were not asked to reveal their exact household income, but the range in which it lies.

Table B4: Responses by State

State	Number of Respondents	% of Respondents	% of State Population
Arizona	530	8.5 %	0.0082 %
California	477	7.6 %	0.0013 %
Colorado	535	8.6 %	0.0108 %
Idaho	292	4.7 %	0.0192 %
Kansas	445	7.1 %	0.0159 %
Montana	197	3.2 %	0.0204 %
Nebraska	308	4.9 %	0.0173 %
Nevada	430	6.9 %	0.0165 %
New Mexico	299	4.8 %	0.0151 %
North Dakota	124	2.0 %	0.0193 %
Oklahoma	446	7.1 %	0.0122 %
Oregon	470	7.5 %	0.0124 %
South Dakota	149	2.4 %	0.0185 %
Texas	467	7.5 %	0.0019 %
Utah	368	5.9 %	0.0134 %
Washington	569	9.1 %	0.0087 %
Wyoming	144	2.3 %	0.0270 %
Entire West	**6,250**	**100 %**	—

The largest share of respondents currently live in a large city (Figure B1). The largest share of respondents also grew up in large cities. A surprising number of respondents reported living in the west more than twenty years (Figure B2).

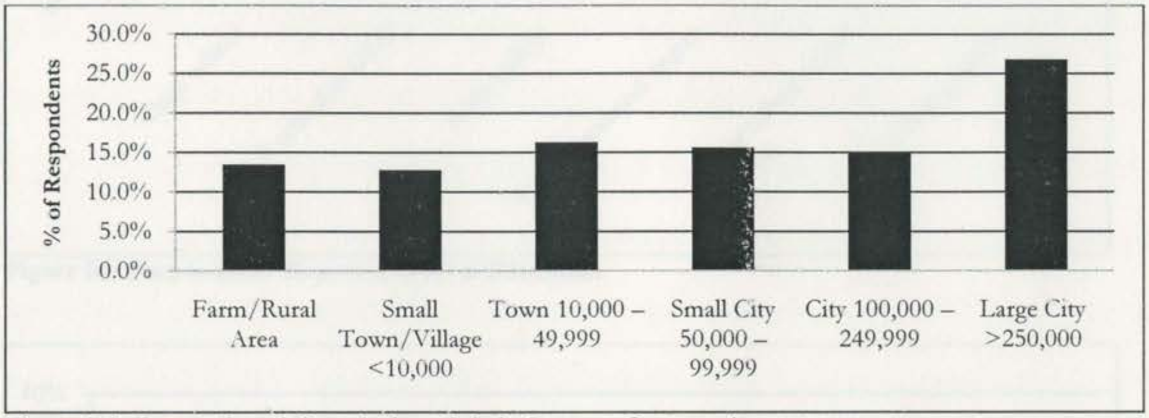

Figure B1: Respondents' Description of their Current Community

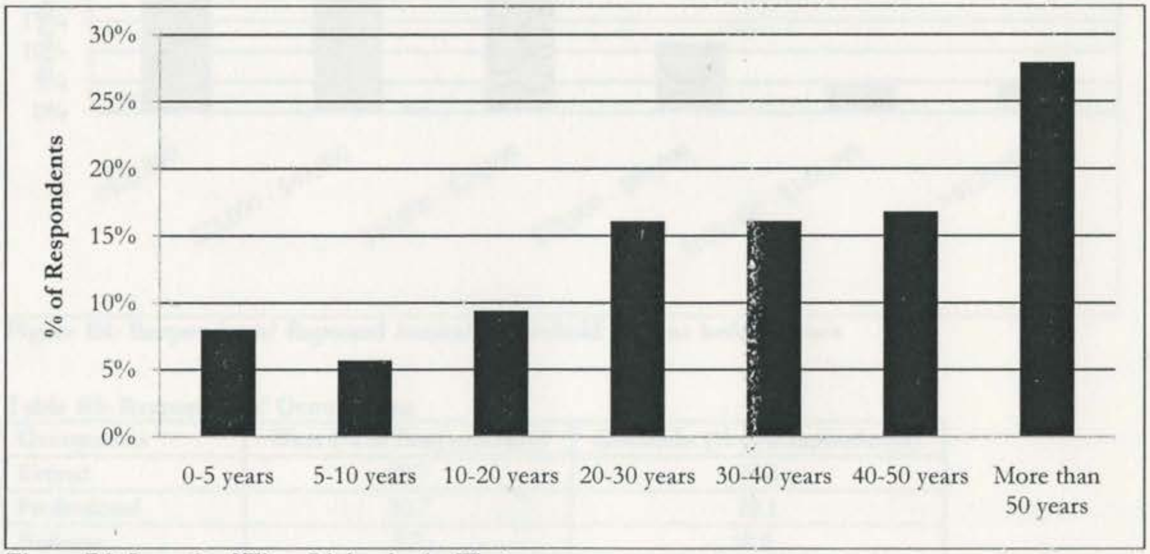

Figure B2: Length of Time Living in the West

Most respondents (81 percent) had some educational training beyond high school (Figure B3). Their annual household income tended to be less than $75,000 (Figure B4). The largest shares of respondents were retired or professional individuals (Table B5).

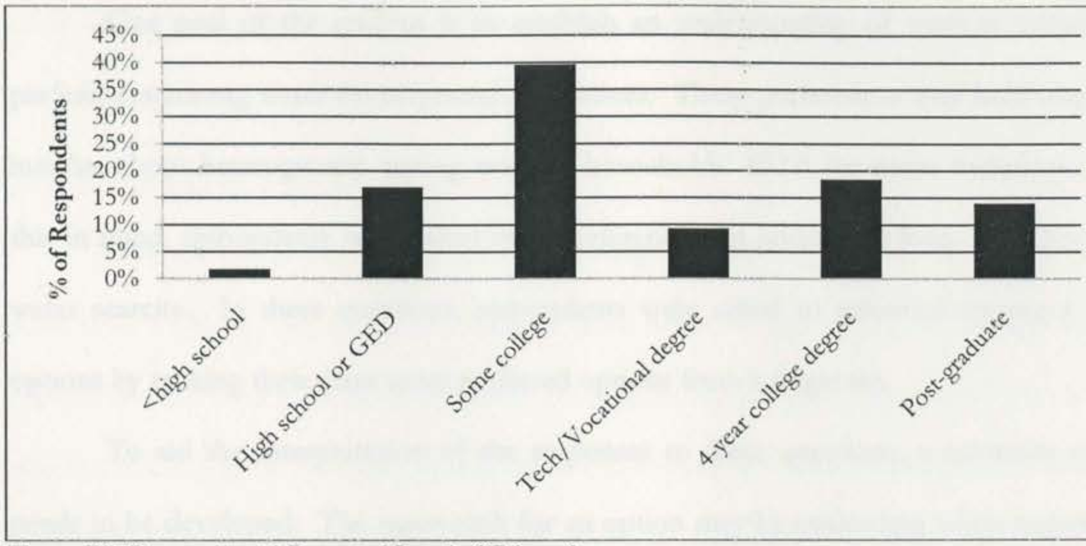

Figure B3: Respondents' Reported Level of Education

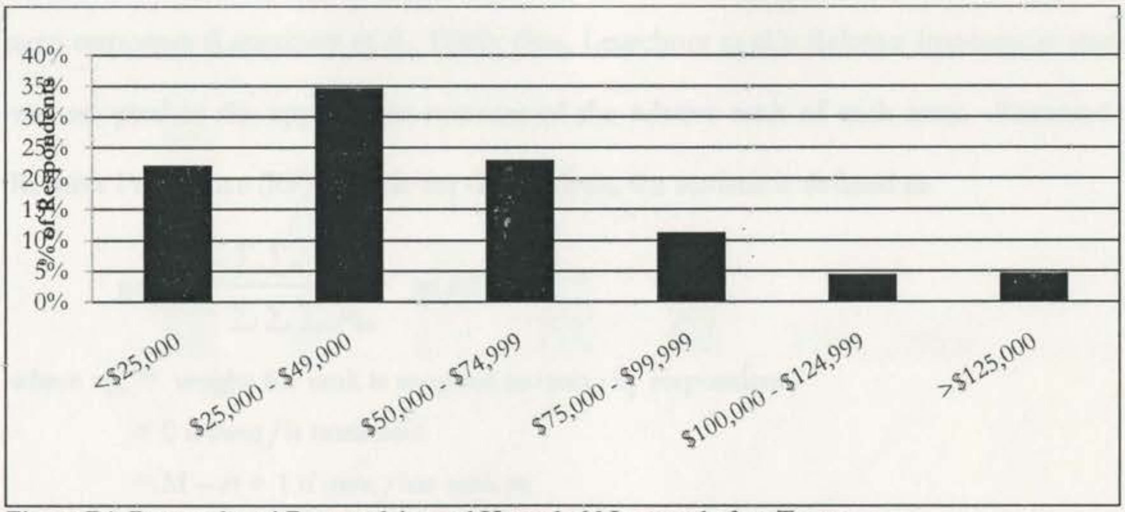

Figure B4: Respondents' Reported Annual Household Income before Taxes

Table B5: Respondents' Occupations

Occupation	West (% of Respondents)	Colorado (% of Respondents)
Retired	28.7	25.4
Professional	20.7	22.1
Business	9.7	8.8
Retail	7.2	6.5
Teaching	5.2	5.8
Student	5.2	5.4
Manufacturing	2.8	2.8
Agriculture	1.3	1.7
Ranching	1.1	0.9
Other	18.3	20.6

Preferences, Perceptions, and Knowledge

One goal of the analysis is to establish an understanding of western households' preferences among water development alternatives. These preferences may hold important insights about heterogeneity among western households' WTP for water initiatives. With this in mind, respondents were asked their preferences for addressing long- and short-term water scarcity. In these questions, respondents were asked to prioritize among a list of options by ranking their three most preferred options from a larger set.

To aid the interpretation of the responses to these questions, a summary statistic needs to be developed. The mean rank for an option may be misleading when respondents are asked to rank a subset of all options because the mean will (presumably) include many zero responses (Leuschner et al., 1988); thus, Leuschner et al.'s Relative Importance statistic was adopted as the appropriate measure of the relative rank of each item. Renamed the Relative Preference (RP) statistic for this analysis, the statistic is defined as:

$$RP_j = \frac{\sum_i \sum_m w_{ijm}}{\sum_i \sum_j \sum_k w_{ijm}} \times 100 \qquad \text{(B1}$$

where w_{ijm} = weight for rank m assigned to item j by respondent i

= 0 if item j is unranked

= $M - m + 1$ if item j has rank m.

RP_j is the percentage of all weights assigned that were assigned to item j. In the present case, $M = 3$, so a respondent's first choice was given a weight of three, while the second choice was given a weight of two and the third a weight of one. The remaining unranked options received a weight of zero. The weights given by all respondents to a *particular* category were then summed and divided by the sum of *all* weights. The resulting percentage is the RP statistic for that category; it represents the proportion of total weights that the category received. The sum of all RP_i's for the alternatives in a given question will equal 100. The RP statistics for several attitudinal questions are reported in the next sections.

Priorities during Times of Water Scarcity

Western states at times experience temporary water shortages[22] for a variety of reasons, such as drought or over-allocation. During these times, there may not be enough water to adequately provide for all water uses, and some prioritization must take place. The uses for which water might be allocated during times when water is limited were grouped into eight categories. Respondents were asked to indicate which of these eight water uses should receive the first-, second-, and third-highest priorities for allocation when water is limited (Figure B5).

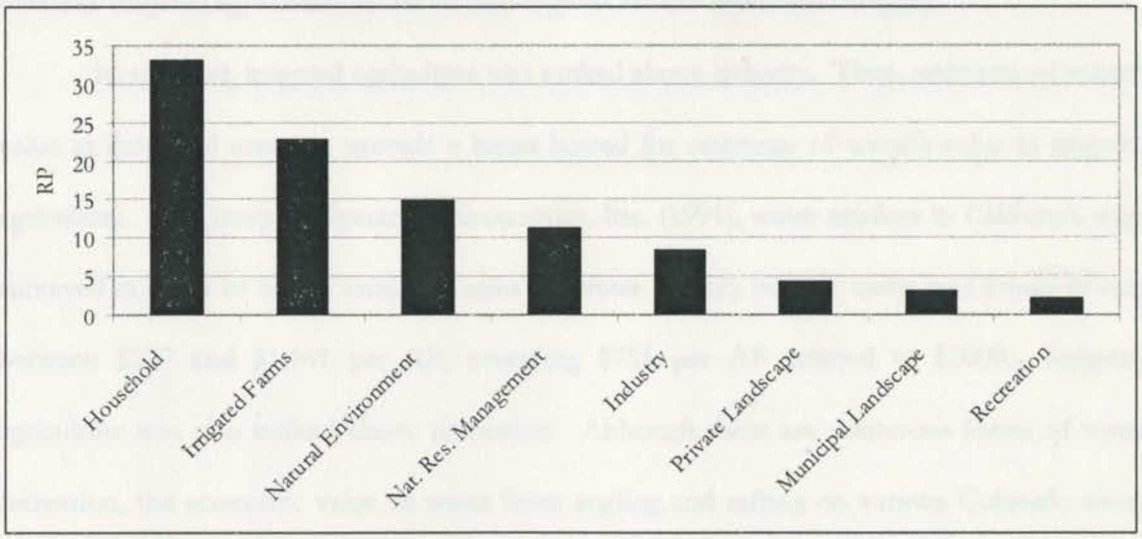

Figure B5: Respondents' Relative Preferences in Times of Short-Term Water Scarcity

Indoor household water use garnered the highest priority among all water uses. The lowest priority was given to recreational uses of water, which mirrors the results of Mahler et al.'s (2004) survey of water priorities of residents of the Pacific Northwest. Thus, while households do not want to reduce their indoor water use, they are willing to cut back on

[22] Here, "temporary" refers to a shortage lasting less than two years. This definition was provided in the survey.

outdoor water uses such as landscaping and recreation—these opinions are in line with those expressed in the focus group process. Irrigated farmland received the second-highest level of priority, providing one indication of the relatively high value that these households place on irrigated agriculture—also in line with the opinions expressed in the focus group process.

However, in the present context, water for the natural environment refers to such things as the provision of fish and wildlife habitat, while water for natural resource management refers to fire suppression and maintenance of stream banks, examples which were provided in the survey. Given the relative similarity between these two categories of water use, it may make sense to also consider the two categories together, in which case they overtake irrigated agriculture as the second-highest ranked water use category.

In any case, irrigated agriculture was ranked above industry. Thus, estimates of water's value in industrial uses can provide a lower bound for estimates of water's value in irrigated agriculture. In a study by Spectrum Economics, Inc. (1991), water retailers in California were surveyed in order to obtain industrial rates for water. Utility potable water was found to vary between \$327 and \$1,141 per AF, averaging \$755 per AF inflated to \$2009. Irrigated agriculture was also ranked above recreation. Although there are numerous forms of water recreation, the economic value of water from angling and rafting on various Colorado rivers has been estimated to range from \$18 to \$358 per AF (Loomis, 2008).

Strategies for Addressing Short-Term Scarcity

If facing short-term scarcity, municipal water providers have several options for acquiring or stretching water supplies. Respondents were given a list of eight such options and asked to list their three most preferred options for meeting short-term water needs. The survey did not include a detailed explanation for each of the options, which avoids any potential bias but also leaves open the possibility that respondents differ in their interpretation of each option. Restricting private and public outdoor watering were by far the most preferred short-term strategies, followed by limits on industry (Figure B6). Permanent water transfers from farms to cities were the lowest ranked strategy—in fact, respondents indicated that they would rather pay higher water rates than dry up agriculture. This suggests that households may be aware of the potential negative effects of permanent water transfers and may take such effects into consideration when forming their preferences for water supply options.

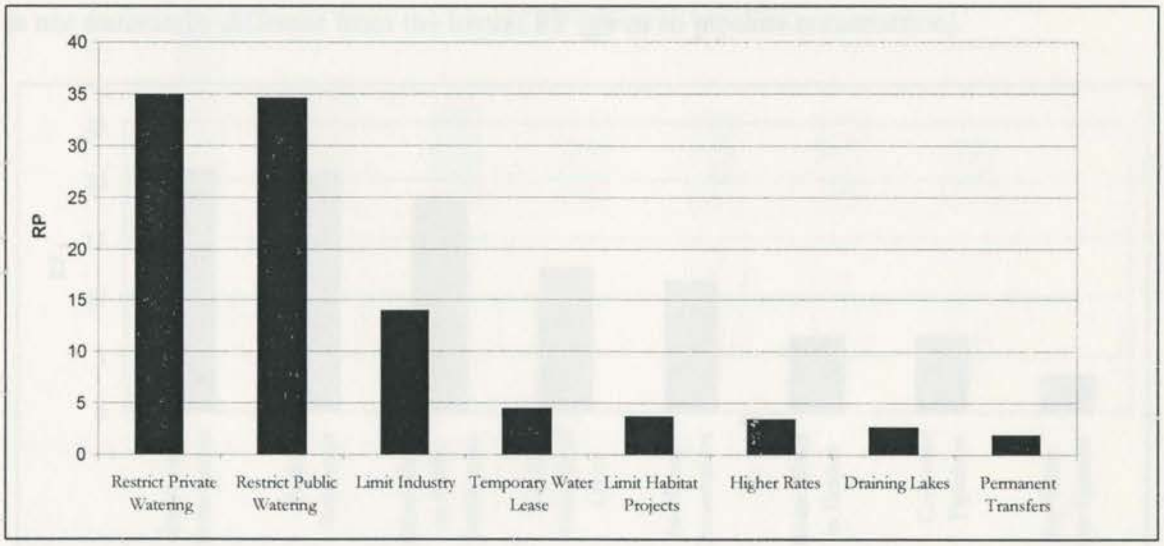

Figure B6: Respondents' Preferred Strategies for Addressing Short-Term Scarcity

Compared to short-term water strategies, the opportunities to develop water for long-term use are more capital-intensive and require longer-term planning. Respondents were given a list of eight strategies for meeting long-term water needs, and were again asked to list their three most preferred options for meeting those needs. The most popular strategies for meeting long term needs were to build reservoirs and to re-use water on private lawns and public landscapes (Figure B7). These findings are in line with Espeland's (1998, p. 8) assertion that people prefer to find new water, or assume that new sources of water will be found, rather than limit their water use.

The least popular alternative was buying water from farmers (3.2 percent). Even when facing long-term drought conditions, households are reluctant to purchase water from farmers, reiterating the call to find alternatives. And this result is not due to the effect of one or a few outlier states—every state gave this option the lowest RP ranking, with the one exception of Montana, which ranked it second-lowest. A t-test reveals that Montanans' RP for this option is not statistically different from the lowest RP (given to pipeline construction).

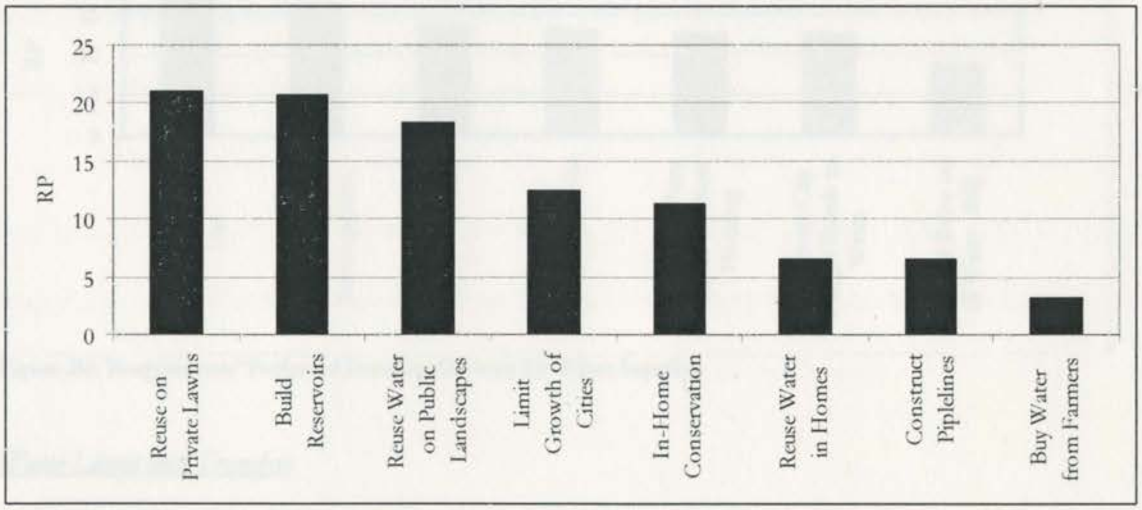

Figure B7: Respondents' Preferred Strategies for Meeting Long-Term Water Scarcity

Preferred Strategies for Funding Water Supply Programs

All strategies for meeting long-term needs will require capital expenditures, and municipal water providers will be charged with acquiring funds. Respondents were given a list of seven opportunities for funding, and were again asked to rank their top three choices (Figure B8). Respondents find it more appealing to place the responsibility of funding additional water supplies on those who are creating the excess demand than to spread the cost equally across all households, preferring to increase water rates proportionately to water use and charge higher fees on new housing. It is no surprise that increasing all water rates was the least popular option—because the majority of increased water demand is a result of population growth, those who already live in the region may feel that they should not have to pay for meeting those new demands. Similarly, those who use less water do not feel they should pay as high a rate as those who use more water.

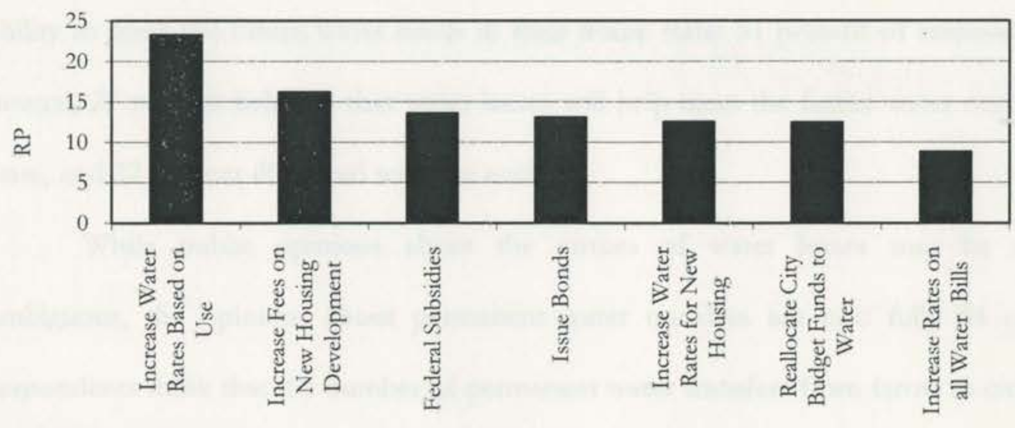

Figure B8: Respondents' Preferred Funding Options for Water Supplies

Water Leases and Transfers

Water transfers and the associated mechanisms for achieving them are the subject of intense policy debate in the western region of the U.S. (Knapp et al., 2003). In this context, respondents were asked their level of agreement with the statement, "Cities should be able to divert water from rural areas if the cities need more water." While nearly a third of all respondents agreed with the statement, a greater proportion disagreed with the statement (Table B6). An even greater proportion of Coloradans disagreed with the statement.

Table B6: Respondents' Support for Cities' Ability to Divert Water from Farms as Needed

	Agree (%)	Disagree (%)	Neither (%)
West	31.0	41.9	27.1
Colorado	25.7	51.6	22.6

While only 36 percent of respondents believed that water leases are more beneficial to rural economies than are permanent water transfers, this is three times the proportion of respondents who disagreed with the notion. Indeed, the majority of responses were neutral, which is likely due in large part to uncertainty about the effect of leases on rural communities, which itself stems from the limited number of lease programs currently in practice. Similar results emerge when considering respondents' opinions regarding leases' ability to meet the future water needs in their home state: 51 percent of respondents were neutral, 27 percent believed that water leases will help meet the future water needs of their state, and 22 percent disagreed with the notion.

While public opinions about the virtues of water leases may be somewhat ambiguous, the opinions about permanent water transfers are not: fully 84 percent of respondents think that the number of permanent water transfers from farms to cities should be limited, while only four percent do not think they should be limited.

Rural Investment

The preceding results show that urban households do not prefer to permanently transfer water from farmers. However, it is not clear whether this is out of self-concern for food security, a local food supply, and lower food prices, or whether it is out of concern for farmers and rural communities. In this context, respondents were asked whether cities should be required to take certain actions after transferring water from rural areas. There appears to be a wide range of actions that would be acceptable to the general public (Table B7). The action generating the greatest agreement was buying and installing equipment to conserve water on farms. Another highly ranked option was for cities to provide job training for rural residents. However, rural development strategies based on boosting human capital will only be successful if integrated with activities that boost demand for skilled workers in the region (Fitzgerald, 1995). Also, while entrepreneurship programs can provide opportunities for growth, the small businesses created are extremely vulnerable and cannot serve as a substitute for other types of employment (Bates and Nucci, 1989). The least-preferred option was for cities to do nothing, again suggesting that urban households are aware of the negative effects of permanent transfers and may have concern for farmers and rural communities.

Table B7: Respondents' Preferences for the Compensation of Rural Communities

Activity	% Agree (West)	% Agree (Colorado)
Conserve water on farms	84.8 %	84.6 %
Financially compensate rural communities	84.3 %	87.5 %
Provide job training	64.1 %	63.5 %
Restore irrigated farmland to native grasses	58.9 %	59.8 %
Create loan programs for start-up businesses	53.3 %	55.1 %
Invest in rural roads and schools	52.7 %	54.1 %
Do nothing	3.1 %	2.7 %

Household Conservation

Household conservation may be one strategy to reduce the demand for water resources. With this topic in mind, respondents were asked to provide their level of agreement with a number of statements about water conservation. Water conservation is a personal concern of 72 percent of all respondents, with 75 percent participating in water conservation strategies in their daily lives. This is encouraging, especially considering that just a decade ago water scarcity seemed to do little to alter individuals' lifestyles (Espeland, 1998, p. 8).

Government Jurisdiction, Mandates, and Perceived Responsiveness

A number of people and groups are in a position to make decisions about the best way to conserve water in our communities. As Figure B9 shows, respondents prefer that that responsibility for conservation decisions fall to households and/or local government.

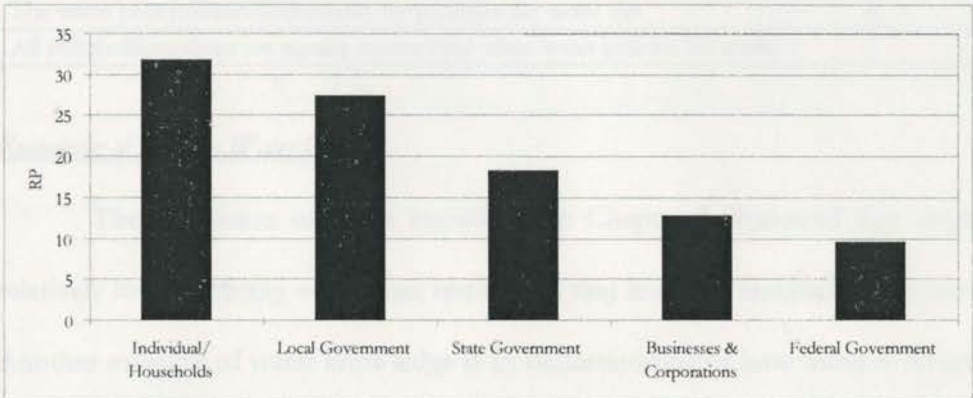

Figure B9: Respondents' Preferences about Who Should Make Water Conservation Decisions

Several policy alternatives exist for managing water resources and water scarcity. Respondents were asked their level of agreement with a number of statements regarding water policy and management. As seen in Table B8, there is strong agreement with the notions that regional land use and water resource planning is needed to manage water scarcity, that public funds should be used to acquire and develop water resources, and that the growth of cities should be limited to manage water scarcity. There is also general agreement that permanent water transfers from farms to cities should be limited. Respondents are not satisfied with current water management and laws, nor do they believe they have enough of a voice in water policy, that policymakers understand their priorities, or that all stakeholder groups are equally represented in water policy decisions.

Table B8: Respondents' Level of Agreement with a Number of Water Policy Statements

Water Policy Statement	Average Likert Score
Regional land use and water resource planning is needed to manage water scarcity	4.3
Public funds should be used to acquire and develop water resources	4.2
The growth of cities should be limited to manage water scarcity	4.0
Water laws need to be changed to better meet today's situation.	4.0
The number of permanent water transfers from farms to cities should be limited	3.8
I am satisfied with the current system of water management.	2.5
I think the public has enough of a voice when it comes to water policy management	2.4
The water policymakers understand my priorities for water use.	2.4
All stakeholder groups are equally represented when water policies are made.	2.3

Knowledge of Relative Water Use

The discussion of water knowledge in Chapter 3 illustrated that respondents report relatively low familiarity with water terms, and that levels of familiarity vary across individuals. Another measure of water knowledge is an understanding of how water is diverted and used in the west. Respondents were asked to rank the top three water users out of eight water use categories their perceptions were then compared to actual water use. Colorado respondents gave the same relative rankings as the entire west, and their responses are discussed here for further illustration. Figure B10 displays Colorado residents' perceived water use rankings, while Figure B11 displays actual surface water diversions in Colorado, excluding water put aside for storage. A comparison of the two graphs reveals a discrepancy between perceived and actual water usage. It is clear that respondents' understate the diversion of water for agricultural use and generally overstate the diversion of water for other uses. As described previously, the development of the survey questionnaire relied, in part, on the discussion of a focus group of technical experts. These experts suggested that public's knowledge of water allocation by uses was very important in addressing future scarcity in the west. Combined with the lack of familiarity with a number of water terms, these results indicate an opportunity for water education in the west.

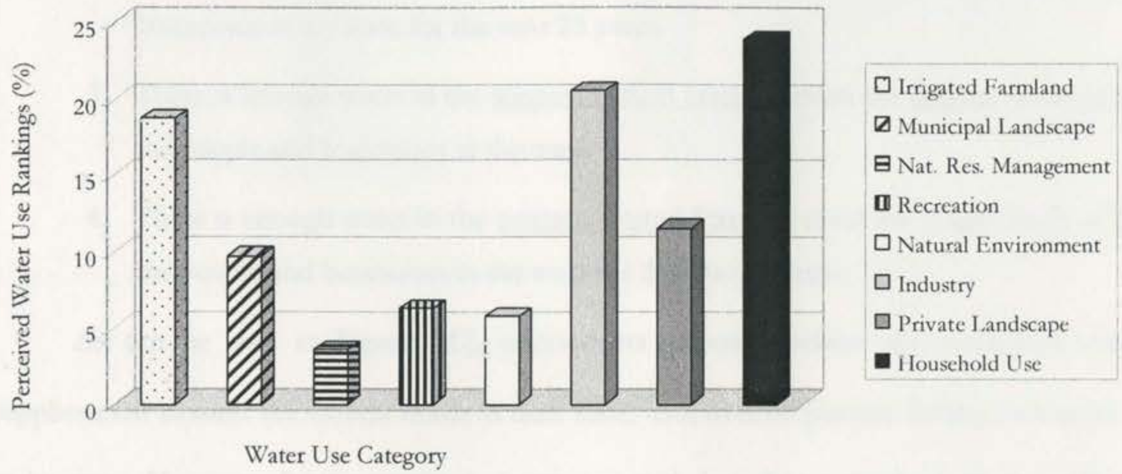

Figure B10: Coloradans' Perceived Water Use Rankings

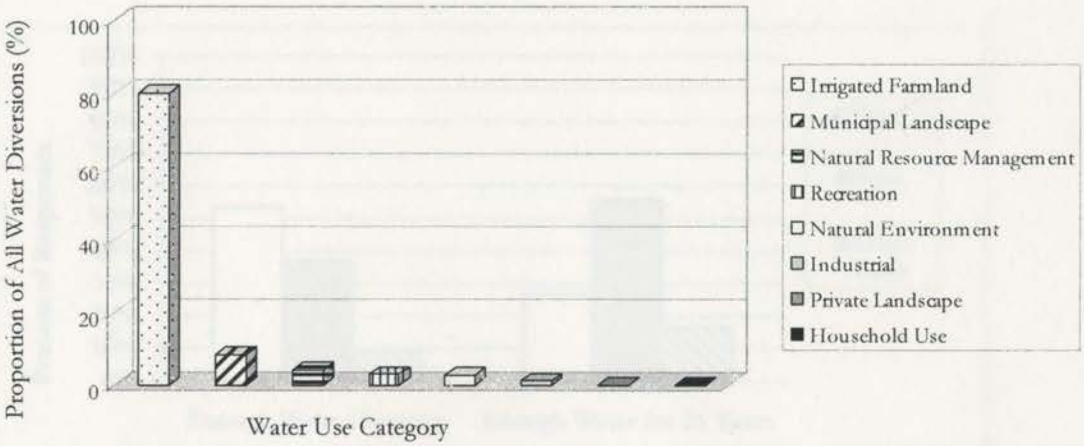

Figure B11: Actual Surface Water Diversions in Colorado (Colorado Division of Water Resources, 2006)

Perceptions of Water Scarcity

In order to gauge their perceptions of current and future water scarcity in their state and the west, respondents were asked to indicate their level of agreement with the following statements:

1. There is enough water in my state to meet the current needs of all the people and businesses in my state.
2. There is enough water in my state to meet the future needs of all the people and businesses in my state for the next 25 years.
3. There is enough water in the western United States to meet the current needs of all the people and businesses in the west.
4. There is enough water in the western United States to meet the future needs of all the people and businesses in the west for the next 25 years.

As can be seen in Figure B12, respondents generally believe that sufficient water supplies exist to meet the current needs in their state, with over 50 percent finding Statement 1 to be true. However, future scarcity is a concern, with less than a third of all respondents finding Statement 2 to be true.

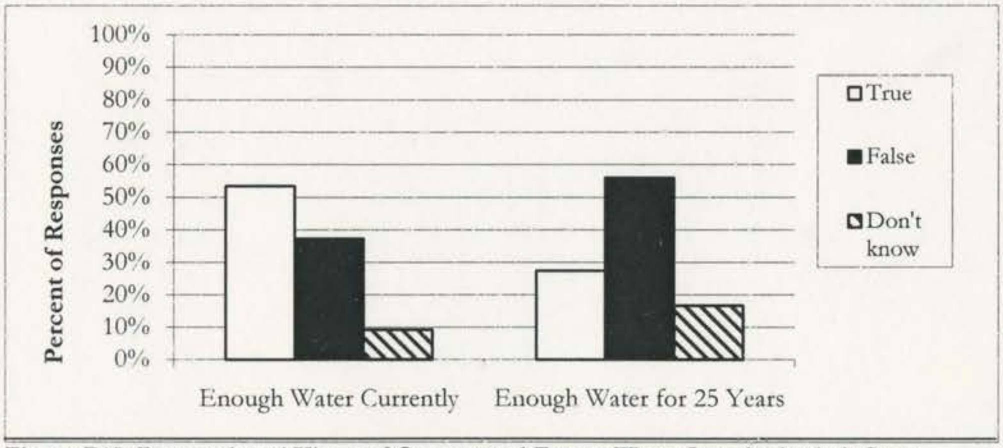

Figure B12: Respondents' Views of Current and Future Water Scarcity in their State

Respondents have a less optimistic view of water supplies across the entire west: less than one-third of the respondents think there is enough water in the west to meet current needs, and only a quarter think there is enough water in the west for the next twenty-five years (Figure B13).

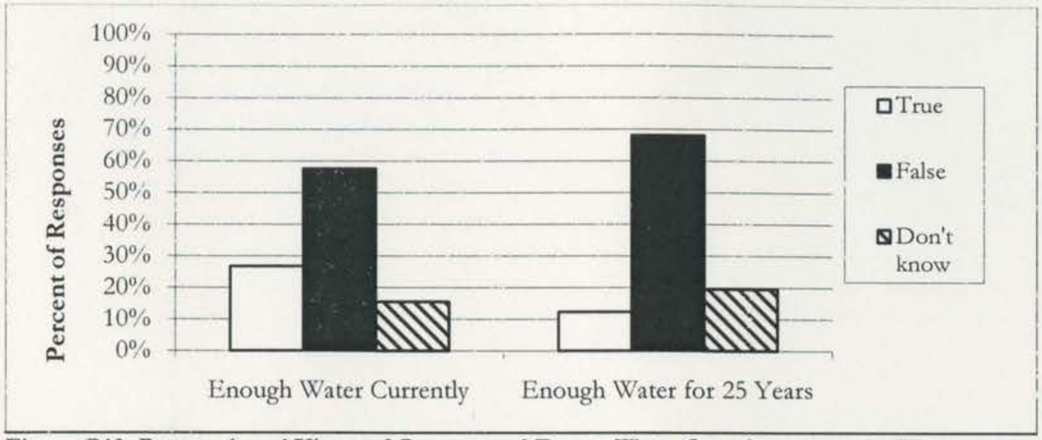

Figure B13: Respondents' Views of Current and Future Water Scarcity across the West