DETERMINANTS AND TRENDS IN WATER RIGHT PRICES: AN ECONOMETRIC ANALYSIS

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May 1994
WWRC-94-06

Technical Report

Submitted to

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U.S. Geological Survey
and
Wyoming Water Resources Center
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The activities on which this report is based were financed in part by the Department of the Interior, U.S. Geological Survey, through the Wyoming Water Resources Center.

ABSTRACT

This study analyzes water right price variation over time. A model based on rational expectations theory is constructed to analyze relationships between identified potential price determinants and water right market prices. The potential effects of speculation also are examined from a theoretical standpoint. Prices of Colorado-Big Thompson project water shares are used to test the theoretical model. The analysis suggests that, more than returns to irrigation, economic and market factors may explain most of price variation.

ACKNOWLEDGMENTS

The authors wish to express gratitude to several employees of the Northern Colorado Water Conservancy District for their help in this study.

Financial support was provided by the Department of the Interior, U.S. Geological Survey through the Wyoming Water Resources Center.

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CHAPTER ONE: INTRODUCTION

1.0 General outlook

Ownership and management of water resources have been of major interest in the semi-arid western United States since the early days of settlement. In this region, control of water traditionally has been linked to economic growth. The notion of water scarcity has become increasingly acute as population and economic activity have grown, and as demand patterns have changed over time (Hartman and Seastone, 1970). One way of dealing with water scarcity is to allow reallocation of water rights through voluntary market transfers, so that water is being used to satisfy higher-valued demand patterns. Actually, water rights are now being commonly transferred throughout the West, typically from agriculture to municipal or industrial uses (MacDonnell, 1990).

The price at which a water right is traded depends on the institutional environment, the commodity's characteristics as well as other factors (e.g., economic situation). However, water right market prices also fluctuate over time, within the same legal structure and for similar characteristics (Michelsen and Young, 1992). More knowledge is therefore needed to achieve the goal of better water management. Wyoming Congressman Craig Thomas says: "[Interior Secretary Bruce] Babbitt is increasing federal control over water resources and if you control the quality and price of water, you can control the Western states and their economies," (reported by The Associated Press in The Laramie Daily Boomerang, April 10, 1994). The scope of this thesis is to investigate a particular water right market in order to better understand water right price variation over time.

1.1 Water right market development

Before describing the process that led to the establishment of markets for water rights, let us first define some terms that appear in the present discussion. In economic terms, a resource is "something that is useful and valuable in the condition in which we find it" (Randall, 1987). Stated this way, the term "resource" encompasses the notion of scarcity: what is not scarce is not a resource. Scarcity (for anything) simply means that the quantity demanded exceeds the amount available. A water resource is a source of water supply, such as a lake, reservoir, stream or aquifer.

A water right is "a collectively recognized access to water resources under specific conditions defined in the right, such as point of diversion, season, location and purpose of use, and quantity of withdrawals" (Saliba and Bush, 1987). It is a property right to surface water (in reservoirs or streams) or to groundwater. Water rights are typically measured in terms of flow (cubic feet per second, gallons per minute) and/or volume (acre-feet, cubic meters). They are generally held by individuals, businesses, municipalities or government agencies, and in many cases can be bought, sold or leased (National Research Council, 1992). The physical distribution and/or transfer of water usually take place in proximity to natural water sources (reservoirs, streams, aquifers) or through the use of more sophisticated features such as ditches, canals, pipelines, or even tunnels.

Water resources regulation in the United States is based upon one or both of the two general doctrines: riparian rights and prior appropriation. These doctrines are fundamentally different, but both aim at defining specific water rights under state law (water resources are considered the state's property). The eighteen states west of the 98th meridian apply essentially the prior appropriation doctrine, which can be summarized as: first in time, first in right. In other words, the first to put the water to beneficial use has the first right, and all water rights are regulated by priority. Therefore, in periods of limited supply, only the earliest rights are entitled water (Jacobs *et al.*, 1990).

Water rights established by the prior appropriation doctrine were initially developed to protect the primacy of mining interests, and then agricultural interests (Gibbons, 1986). As the demand for water grew, control over surface water appeared necessary to increase the usability and reliability of natural water supply. New water storage and delivery systems were built to provide users with secure and additional water rights. Moreover, with the rapid urbanization of the western United States over the past several decades, municipal and industrial consumptive demands for water have increased sharply. At the same time, instream uses of water for fisheries maintenance, recreation and environmental preservation have gained in importance, creating new needs for additional water (National Research Council, 1992).

However, the process of water development has become increasingly costly, both in financial and environmental terms (Howe *et al.*, 1990). The best storage sites have already been used, augmenting the difficulty and cost of creating new reservoirs. Furthermore, the booming public interest in instream flows and preservation of natural areas and wildlife is changing the concept of water management. Consequently, water development projects are no longer assured to be approved, as illustrated by the Environmental Protection Agency's veto of the Two Forks reservoir project in Colorado in 1990.

The normal flows of many western rivers are fully allocated, and new water supplies are difficult to develop. Moreover, in some areas, ground water is being used at a rate faster than it can be naturally replenished. Consequently, there is increasing attention on transferring water rights from one location or use to another. Typically, the market mechanism reallocates resources, in this case water rights, from lower-valued to higher-valued uses. Water right transfers as an alternative to water development projects have been advocated not only by economists, but also environmental interest groups, engineers, government agencies, etc. (Michelsen and Young 1993; National Research Council, 1992; Shupe *et al.*, 1989; Howe *et al.*, 1986; Wahl and Osterhoudt, 1986). The western United States water economy is now moving from the expansionary phase to the mature phase (Randall, 1981). In other words, "we are moving from an era premised on the continual development of new supplies to a reallocation era premised on the better use of existing supplies" (National Research Council, 1992). Reallocation of water rights can take different forms, ranging from exchanges and temporary leases to permanent changes in the use and ownership of water rights. Today, water right transferability is generally being encouraged through legislation to improve the efficiency of water use. This move is evident from "the removal of some formal barriers to transfers, implementation of existing laws in ways more conducive to transfers and, in a few cases, the enactment of legislation to encourage transfers" (National Research Council, 1992). As a result, some areas have witnessed the development of water right markets, where property rights to water are being traded among economic agents, typically from farmers to municipal or industrial water users.

A study by MacDonnell (1990) shows that water market transfers are actually occurring in the western states, frequently in Colorado, New Mexico and Utah, and less frequently in other states (e.g., California and Wyoming). The study reported that from 1975 to 1984: 3,853 transfer applications had been filed in Utah; 1,133 in New Mexico; 858 in Colorado; and 42 in Wyoming. Apart from the complete appropriation of regional water rights and anticipated growing demand for water, existing institutional structures appear to be a major influence in water right market activity. In fact, although market reallocation is being encouraged in most western states, water right transactions are still paradoxically highly regulated. Transfers are usually subject to a public interest review (e.g., state agency or water judge) and this process can be long and expensive.

1.2 Economic rationale behind water market development

Reallocation of water rights through voluntary markets constitutes an alternative to building new water development projects, and at the same time promotes economic efficiency. The development of water right markets is based on the perception that economic gains may be captured by transferring water from lower-valued to higher-valued uses (Saliba and Bush, 1987).

Moreover, despite the rapid urbanization of the West, most of the water is still being used by the agricultural sector. Howe *et al.* (1990) state that, according to U.S. Geological Survey data, "80% of all water diversions and nearly 90% of all water consumption in the western United States occur in irrigated agriculture." This suggests that reallocating a small portion of the water away from agriculture could satisfy growing nonagricultural demands for decades.

1.3 Problem presentation

Critical to the water right transfer process and the evaluation of water supply alternatives is knowledge about water right prices. Price is a crucial element for evaluating the economic benefits and costs of any market transfer. Decision about whether or when to purchase or sell water rights, lease temporary rights, invest in water development projects or how to analyze transaction proposals requires information about water right prices and trends. Similarly, prices for water rights in well-established markets may help to determine optimum supply expansion over time (Howe, 1993). However, very little knowledge is available that can provide potential buyers, sellers and management institutions with the information needed to understand water right market price relationships or to develop forecasts of water right prices.

Prices of water rights vary widely, from a few hundred dollars or less to several thousand dollars per acre foot. Variations in the prices of different water rights are often attributed to differences in supply reliability (legal priority and hydrologic conditions), type of use, diversion location, transaction costs or the amplitude and evolution of water demand (Michelsen and Young, 1992).

However, dramatic variations in price also have been observed over time for specific water rights that have the same supply reliability, supply location and demand conditions. A good illustration of this is provided by the Colorado-Big Thompson (CBT) water right prices (Figure 1-1).

Prices of Colorado-Big Thompson Water Shares
1961-1993

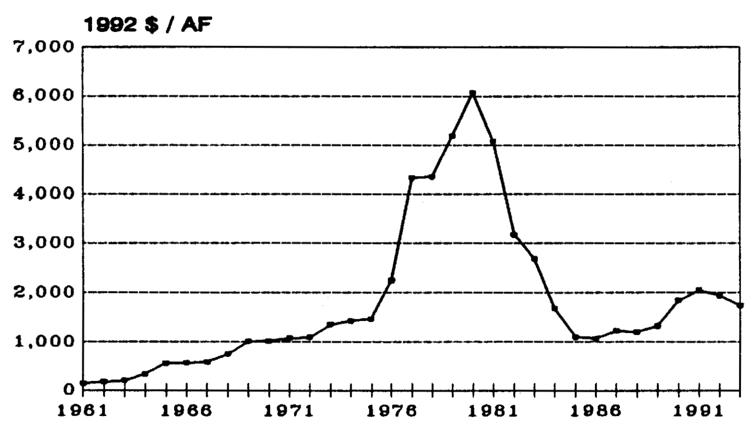


Figure 1-1

How can we explain these large variations in price over time? What are the driving forces that cause prices to increase or decrease? Does the consideration of potential speculative forces make any sense? Are there any boundaries to price fluctuation, i.e., a minimum and a maximum price?

1.4 Objectives

The primary objective of this thesis is to better understand the mechanisms of water right price evolution. More specifically, the research is aimed at:

- Identifying specific factors that can help determine water right market prices on a long term basis. This identification will be performed from both a theoretical and an empirical perspective. Economic, sociologic, financial and climatic variables will be examined and selected to constitute a set of accurate price determinants. Also, in order to help decision-makers and analysts in their forecasts, reliable indicators of water right price evolution (i.e., not necessarily involving direct causal relationships) will be investigated.

- Integrating the appropriate economic theories in order to adequately represent the interactive forces that drive water markets. This step is crucial because it determines the structure of determinant-price causal relationships, and therefore the accuracy of the analysis.

- Modeling, quantifying and testing for water right price-determinant relationships. A dynamic econometric model based on economic theory and identified price determinants will be constructed, tested and analyzed according to our objectives and hypotheses. This model construction is intended to provide an accurate representation of the investment decision process and be applicable to different water markets.

1.5 Thesis overview

This chapter introduced the problem and the general background, as well as the study's objectives. Chapter Two presents the theoretical background of water right market price analysis. The methodology developed to meet the objectives is detailed in Chapter Three. Chapter Four describes the case study area. The data sets used in this research are described in Chapter Five. A descriptive preliminary analysis is performed in Chapter Six. The empirical tests and model results are presented and discussed in Chapter Seven. Conclusions and recommendations for future research are presented in Chapter Eight.

CHAPTER TWO: THEORETICAL AND EMPIRICAL BACKGROUND

2.0 Introduction

A significant volume of literature has been published that deals with water transfers, water values and water legislation. However, very few studies have focused on the explanation of water right market prices. To better understand the current problem, the rationale behind market growth and price fluctuation is developed, both from a theoretical and an empirical standpoint. In turn, the rare previous studies on water right prices are presented. Finally, the extensive theoretical economic literature on rational expectations, speculation and investment theory is reviewed as a basis for the analysis methodology.

2.1 The economics of water transfers

2.1.1 A theoretical competitive market model

In order to illustrate the specific mechanisms of water transfers, let us elaborate a simple model of a regional market for water. For simplicity, we will assume that only two types of participants are present: agricultural users (who hold most of the water) and municipal users who seek more water as urban population and economic activity are increasing. The regional supply of water is assumed to be fixed, exempt from hydrologic fluctuations, interregional transfers or new development projects. The necessary conditions for an efficient market to develop (Randall, 1987) are assumed to be present, i.e.:

- property rights are defined, enforced, exclusive and transferable
- information is readily available to all market participants
- single economic agents are price takers and cannot strategically affect market prices.

Furthermore, property rights for water are supposed to be homogeneous in terms of physical and legal characteristics, and transaction costs are assumed negligible. In such a setting, the demand for water can be represented as follows:

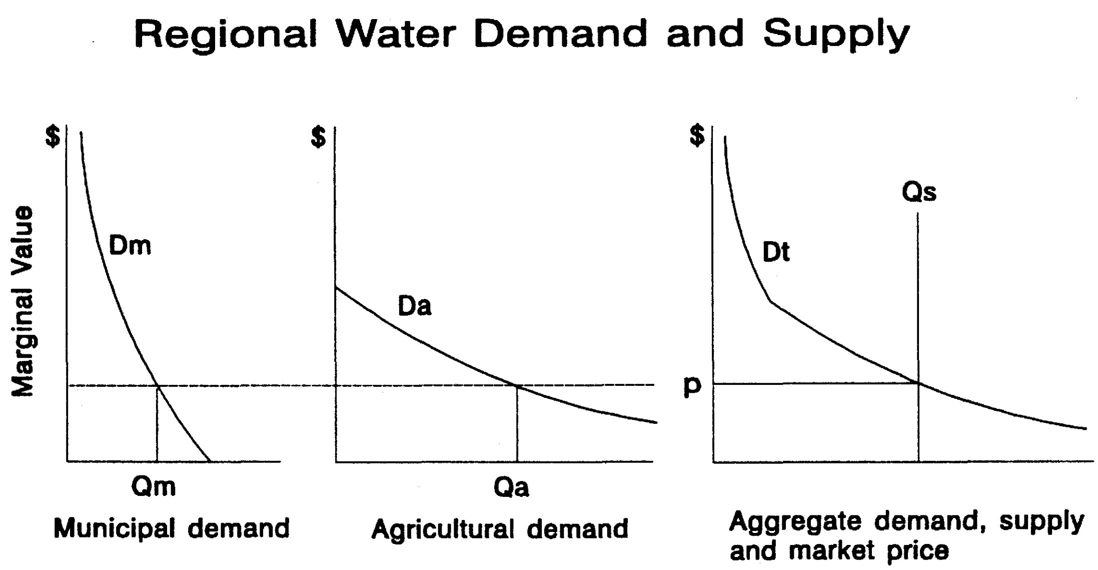


Figure 2-1

The aggregate demand curve D_T is the horizontal summation of the demand for water in municipal uses (D_m) and agricultural demand (D_a). A water demand curve represents the relationship between the total quantity demanded in each sector and the marginal value of water, i.e. the value of the last unit used. Both sector demand curves are downward sloping, according to the law of diminishing marginal returns:

each additional unit yields less satisfaction or returns than the previous one. The slope of a demand curve represents its own-price elasticity, the percentage change in quantity demanded for a one percent increase in price. As shown on the graph, municipal water demand is much more inelastic (i.e., less responsive to price changes) than agricultural demand. Also, the first units of water have a much higher value in urban uses than irrigators are, on average, willing to pay (Young and Gray, 1972).

The market price is determined by the intersection of aggregate demand and aggregate supply and, in turn, sets the quantity demanded in each use according to the specific demand relationships. Overall, municipal demand for water involves much smaller amounts than agricultural demand. The total economic benefits associated with each water use are defined as the sum of the marginal benefits and correspond to the area below the demand curve and up to the quantity utilized. Therefore, water used for municipal purposes carries a higher average value per unit than water used for crop irrigation. In theory, however, the market price equates marginal values across uses.

Since the regional supply of water is assumed fixed, any increase in the urban demand (i.e., a shift of the demand curve to the right) has to be satisfied by a transfer of water from the farming sector to the municipal sector. Such a transfer is depicted in Figure 2-2.

The increase in total demand fixes a new, higher market price (p') which determines the quantity to be transferred in order to meet the new municipal demand

Reallocation of Water From Farmers to Cities

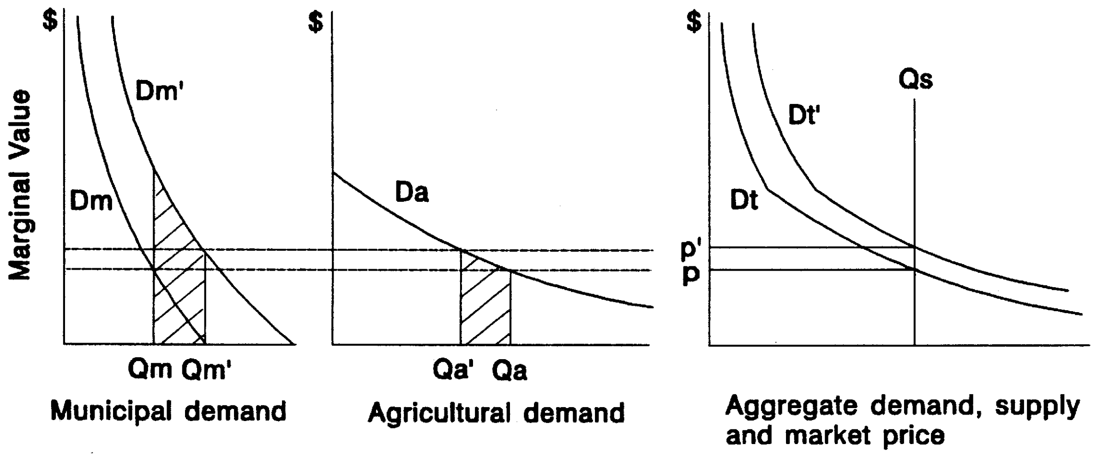


Figure 2-2

(D_m'). Transferred water yields higher economic benefits in the new use (difference between hatched areas), therefore providing the economic justification for the reallocation.

2.1.2 Real versus hypothetical situation

The market model presented above depicts an ideally efficient setting where the marginal value of water is equal across uses and where a transfer would automatically occur whenever economic benefits could be gained from reallocating water. The real life situation, however, diverges significantly from this model for several reasons. Potential sources of imperfect competition are numerous. First of all, water rights are rarely homogeneous: the prior appropriation system attributes a priority date to each of them, affecting their reliability in dry years and therefore their value. The appropriation system allocates water not according to economic productivity, efficiency or value, but according to the time of first use. Since the highest priority water rights are typically held by agricultural users, the relatively lower-valued irrigation uses will be allocated water in dry years at the possible expense of higher-valued but lower priority uses. Consequently, the marginal value of water is not necessarily equivalent across uses. Plus, every type of water use (e.g., agricultural, municipal, industrial...) encompasses a variety of uses with specific returns, thus yielding a variety of marginal values. Second, the definition of water rights is sometimes unclear. For example, some water rights are quantitatively specified only in flow units (cubic feet per second) with limited reference to the length of the diversion period. Also, most water rights have no qualitative description. Third, water rights are not always easily transferable from one place of use to another, and only the estimated consumptive portion of the right can be transferred in order to protect return flows for downstream users. Fourth, transaction costs involved in a water transfer can be very high due to the public review process, search of information, long delay time, etc. Finally, uniform information may not be readily available to all potential market participants.

All the above deviations from a hypothetical situation lead to increased uncertainty and costs, and probably explain why real markets for water are not as responsive nor as smooth as our theoretical market model. Consequently, market prices may not correspond to marginal values in different uses, and large value differentials may exist, even at the margin. In fact, these differences in use values are the driving force behind market development and price fluctuations when they overcome the sum of costs incurred. Many economists have attempted to estimate the economic value of water in various uses. The next section presents the most used valuation techniques and some water value estimates.

2.2. Variability of water value within and across uses

2.2.1. Water use in the west

Most of the water in the west (80 to 90 percent) is still owned and used in irrigated agriculture (National Research Council, 1992). Therefore, many studies naturally focused on assessing water value in crop production. Basic irrigation procedures were introduced in the western United States by the early settlers, but it was not until the end of the nineteenth century that irrigation techniques were refined and large projects developed. The west then entered a period of rapid, sustained growth and prosperity. The irrigation use trend stabilized in the second half of the twentieth century, and is now stable at best in some areas and under stress or declining in others (National Research Council, 1992).

Although consumptive use of water for municipal purposes accounts for less than 10 percent of total water consumption in the United States, it is often viewed as the most vital water use (Gibbons, 1986). In fact, as emphasized by Colby (1989), "[m]unicipal water demand for current and future use is a key force in Southwestern water markets." Municipal water demand includes a variety of different water uses. Domestic or residential water uses comprise indoor utilization for drinking, cooking, bathing and washing, as well as outdoor usage for lawn watering, car washing or swimming pools. Public water uses include firefighting, maintenance of public buildings and grounds, plus other uses such as commercial water consumption in stores, restaurants and small businesses. Generally, residential uses represent the largest part of municipal water demand. It is also worth noting that the consumption pattern changes with seasons, outdoor uses being negligible in winter. Consequently, many studies come up with two different demand relationships, one for summer water demand and one for winter demand.

Due to the processes in which water is involved in the industrial sector, the quantity of water consumed is small compared to the quantity withdrawn; in the United States, industrial withdrawals account for about 43 percent of total withdrawals, but represent only 9 percent of the consumptive use of water (U.S. Water Resources Council, 1978). The percentage of water withdrawals actually consumed in industry is smaller than in irrigation (around 55%) and municipal use (25%). Four industrial sectors account for 84 percent of total industrial water use: primary metals, chemicals, petroleum and coal products, and pulp and paper (Gibbons, 1986). Industrial water use other than power generation is mainly concentrated in the eastern half of the country, plus the states of Idaho and Washington.

As underscored earlier, the public's and water management agencies' interest in instream flows has considerably increased over the past decades, especially in the west where water scarcity is at issue and outdoor activities are often concentrated around lakes, rivers and streams (Colby, 1989). Fishing, kayaking and rafting require adequate streamflows, as do wildlife preservation and channel morphology maintenance. However, these demands usually have not been recognized by allocations under the appropriation system of water rights. In addition, economic allocation is made more difficult because most of these are non-market (value) uses requiring other types of estimation techniques.

2.2.2. Valuation methods

Given the numerous potential sources of imperfect competition in markets for water rights, observed prices rarely constitute ideal measures of value (Colby, 1989). Land-water value differentials are sometimes used to value irrigation water in regions where both dry and irrigated land are present and comparable (e.g., Taylor, 1987). However, use of nonmarket valuation methods is usually preferred to the sales comparison approach because they allow water valuation in different uses and situations. Non-market techniques to estimate the value of water include production value (factor input) methods, contingent valuation and travel cost methods, and the least-cost alternative.

Water as a production factor

When water is used as an input in a production process, which is the case in agriculture and industry, methods can be applied to estimate the contribution of water to the final product. A commonly used method is residual valuation, and has been widely applied in estimating irrigation water values. The residual valuation method requires information about all input costs except one - water. Subtracting all non-water input costs from the total revenue yields a residual value, which can be viewed as the maximum price the operator could pay for the unpriced input (water) and still break even. This residual thus represents the on-site value of water, which, divided by the amount of water utilized, reflects the maximum value, or willingness to pay, of water in this production process. Residual valuation analyses can also be performed using linear programming tools; the shadow price of water is the marginal contribution to profit, i.e., total revenue minus non-water costs, of an additional unit of water.

Another approach that has been used to estimate irrigation water value is the crop-water production function. With this method, the marginal physical productivity of water is calculated through controlled experiments, all other inputs being held constant. The marginal value of each increment is equal to the corresponding marginal physical product times the crop price. The actual physical productivity of water is often difficult to determine and necessitates costly experimental designs. Therefore. this method has not been used as widely as the farm-budget residual method.

Estimating the demand curve for water

Marginal values of water in municipal uses or in instream and recreational uses are usually derived from prior estimation of the demand curve for water. The most commonly used techniques for estimating consumers' willingness-to-pay (thus, the demand curve) include the contingent valuation method (CVM) and the travel cost method (TCM). The CVM relies on direct questioning to estimate the change in consumers' behavior due to a change in water supply or price. This technique is used to estimate the elasticity of demand and consumers' willingness-to-pay for municipal water, based on a hypothetical change in the price schedule. It is also used to estimate how much potential river and outdoor enthusiasts value a change in a river flow (usually in periods of low flow). The TCM is typically used to estimate the willingness-to-pay for recreational water. It attributes a value to water based on travel expenditures actually spent during water-related recreational trips. The CVM and TCM can be used independently or in combination.

The least-cost alternative approach

Another procedure that has commonly been used to evaluate the willingness-to-pay for water is the least-cost alternative technique. This approach is based on cost minimization, and does not produce the maximum willingness-to-pay for water, but rather a backstop price above which other alternatives will be preferred. Purchasing water rights is not the only way to get more available water: alternative solutions exist, like recycling water and reusing it (commonly practiced in industry) or building a new water storage (sometimes envisaged by municipalities). If market prices rise beyond the cheapest alternative solution's cost, this alternative solution will be preferred and market transfers will stop. In other words, the least-cost alternative method computes a ceiling level above which market prices should never go. It is worth noting that this technique relates to cost minimization and does not provide any insight on the demand function. The assumptions made with this technique are that economic agents act as price takers and that information is fully available to everyone.

2.2.3 Capitalization of annual values

The techniques described above produce annual value estimates that are not directly comparable to water market prices. However, annual values can be capitalized into a long term value (comparable to the price of a perpetual water right) using the following relationship:

$$PV\,[v(t)] = \sum_{t=0}^{T} \frac{v_t}{(1+r)^t} \qquad (1)$$

where PV[v(t)] is the present value of a stream of annual benefits v_t and r is the discount rate. Capitalized values represent the long run value of water or the maximum price potential buyers would be willing to pay to acquire additional water rights. If v_t is constant over time, it can be extracted from the summation sign and a capitalization factor can be computed. Using a five percent real (net of inflation) discount rate over a thirty year period, the capitalization factor is 16.37. This value will be used subsequently to transform annual values into capitalized values for water.

2.2.4 Water value estimates

This section is based for the most part on D. Gibbons' publication "The

Economic Value of Water" (1986) in which she provides an extensive review of published empirical estimates for water value. It is worth noting that both average and marginal value estimates are found in the literature, although marginal estimates are commonly presented since they are the most comparable to market prices. All reported water values are expressed in 1992 constant dollars, using the GNP implicit price deflator. Annual values are capitalized to ownership values using a real discount rate of five percent.

2.2.4.1 Water values in agricultural uses

The approach that has been applied most often to valuing irrigation water is the residual valuation method, using the crop enterprise budget (factor input cost) analysis. Water use and values are typically estimated using mathematical optimization models. Some typical results obtained using this approach are presented in Table 2-1.

This summary makes it obvious that a wide range of values for irrigation water have been reported. As noted by Colby (1989), crop prices received by farmers appear to be a dominant factor in determining the marginal value of water in irrigation. Specific high-valued crops can yield extremely high maximum willingness-to-pay for water. However, those crops are limited in terms of acreage and water usage, and the bulk of irrigation water in most western states is applied on hay, corn, and wheat for which water values are lower (National Research Council, 1992).

Table 2-1: Value Estimates for Water in Crop Irrigation

Author, year and study area	**Annual Values** (1992 $ / Acre-foot)	**Capitalized values** (1992 $ / Acre-foot)
Kelso *et al.* (1973); Arizona	$5 for grain sorghum to $280 for cotton	$82 to $4584
Shumway (1973); California	$25 for safflower to over $68 for melons.	$409 to over $1113
Martin and Snider (1979); Arizona	$39 for grain sorghum to $118 for sugar beets; $199 for lettuce to $1672 for dry onions.	$638 to $1932 $3258 to $27375
Gisser *et al.* (1979); Four Corners	$5 to $34 (non crop-specific)	$82 to $557
Young (1984); Colorado	<$38 for alfalfa and irrigated pasture to about $38 for corn	<$622 $622
Michelsen (1988); Colorado	$15 for alfalfa $45 for corn $56 for pinto beans $59 for malt barley	$245 $737 $917 $966
USDA Research Programs (1982-83); performed in six western states (Crop-Water production function technique) (Gibbons, 1986)	From $25 for grain sorghum (AZ) to $659 for tomatoes (CA) to $1179 for potatoes (ID)	$409 to $10789 to $19303

1992 dollars per acre-foot; capitalization at 5% discount rate over 30 years.

2.2.4.2 Water values in municipal uses

The majority of municipal demand studies have centered on consumers' response to price changes, that is, on price elasticity rather than water values. As explained earlier, demand price elasticity depicts the percentage change in the quantity demanded for a one percent change in price. Residential water demand tends to be very inelastic, reflected by relatively steep demand curves. Reported annual elasticities vary from -0.02 (Wong, 1972) to an extreme -1.57 (Howe and Linaweaver, 1967), with usually less extreme figures (Table 2-2).

Water demand in the summer is less inelastic than in the winter. Moreover,

Table 2-2: Elasticity Estimates for Municipal Water Demand

Author(s) and date	Location	Elasticity estimates
Gottlieb (1963)	Kansas	-0.66 to -1.24
Howe and Linaweaver (1967)	U.S.A.	Total: -0.40 Winter: -0.23 Summer: East, -1.57 West, -0.70
Wong (1972)	Illinois	-0.26 to -0.82
Grima (1972)	Toronto (Ontario)	Total: -0.93 Winter: -0.75 Summer: -1.07
Foster and Beattie (1979)	New England: Midwest: South: Plains: Southwest: Pacific Northwest:	-0.43 -0.30 -0.38 -0.58 -0.36 -0.69
Billings and Agthe (1980)	Tucson (Arizona)	-0.39 (log), -0.63 (linear)
Billings and Agthe (1987)	Tucson (Arizona)	-0.40 to -0.57
Thomas and Syme (1988)		-0.20

according to Nieswiadomy (1992), water own-price elasticity is higher in the South, where water demand is more affected by outdoor uses, than in the North. Although price elasticity is useful in measuring how consumption patterns will be affected by a price change, it does not provide information on how much urban water users are willing-to-pay for water. One thing is certain, however: at the limit, as water supply moves toward zero, the marginal value of water is extremely high.

Young and Gray (1972) estimated the annual value of water for indoor domestic uses to be around $381 per acre-foot, and about $215 per acre-foot for outdoor uses. Gibbons (1986) reported annual marginal water values corresponding to a 10 percent reduction in water supply of about $136 per acre-foot in winter and $46 per acre-foot in summer for the city of Tucson, Arizona. The corresponding capitalized values are given in Table 2-3. However, municipal water values are very difficult to assess given the absence of data on consumers' response to price variability and few water value estimates have been reported.

Table 2-3: Capitalized Values for Water in Municipal Uses

Young & Gray (1972)	Indoor uses: $6238	Outdoor uses: $3520
Gibbons (1986)	Winter: $2226	Summer: $753

1992 dollars per acre-foot; capitalization at 5% discount rate over 30 years.

Lastly, it is important to note that the value of treated and distributed water does not compare with the value of raw water (Young, 1984). In the city of Tucson, the cost of purchasing raw water accounts for only 12 percent of the delivered potable water price (Colby, 1989). A comparable estimate was given by Bode (1993) for the City of Fort Collins (CO).

2.2.4.3 Water values in industrial uses

In most cases, water accounts for only a small portion of overall production or processing costs, and consequently the demand for water in industry is quite inelastic. A study by Anderson and Keith (1977) found that a $338 per acre-foot increase in the price of water would result in only one to two percent increase in coal-fired plants electricity production costs. Due to the lack of empirical data to derive precise demand functions for water, the least-cost alternative approach is commonly used to estimate the industrial users' willingness-to-pay for water. This method considers the cost of alternatives such as recycling existing water supplies or adopting another technology as the maximum price users would pay to acquire additional water rights. Table 2-4 summarizes a few industrial water value estimates and the corresponding capitalized values for different types of industry.

Table 2-4: Water Value Estimates in Various Industrial Uses

Author & year	Type of use & industry	Alternative to purchasing water	Annual estimates 1992 $/AF	Capitalized values 1992 $/AF
Russel, 1970	Cooling (electricity) Cooling (refineries)	Evaporation tower Evaporation tower	$8 $19	$131 $311
Plotkin et al. 1979	Cooling	Wet-dry systems Totally dry systems	$1576 $2200	$25803 $36019
Kollar et al. 1976	Process water in cotton textile indus.	First recycling Further recycling	$225 $1059	$3683 $17338
Gibbons, 1986	Meat packing industry	Recycling waste-water	$552 to $770	$9037 to $12607
Gibbons, 1986	Hydropower generation	Coal-fired steam plants Gas-turbine plants	$33 $81	$540 $1326

1992 dollars per acre-foot; capitalization at 5% discount rate over 30 years.

2.2.4.4 Water values in instream uses

Several instream uses such as recreation and wildlife habitat do not have any markets that provide information about the value of water, or willingness-to-pay, in these uses. Therefore, non-market valuation techniques such as contingent valuation surveys have been used to estimate instream values for water. However, most of the studies done in this area produce values for the recreational site or activity in units of dollars per user day, but very few have attempted to assess the intrinsic value of water in dollars per acre-foot. Values reported in the following section are expressed in 1992 dollars.

Daubert and Young (1981) used an entrance-fee bidding game to estimate the value of fishing, shoreline recreation and white-water activities on the Cache-la-Poudre river (Colorado). For periods of low flows, participants valued an additional acre-foot of water around $27 for fishing and $19 for shoreline recreation. Those values dropped to zero at higher flow levels, and white-water activities exhibited constant marginal returns of $10 per acre-foot. Walsh *et al.* (1980a) studied the value of recreational water at nine sites along Colorado mountain streams and found that the optimal flow for recreation purposes was about 35 percent of maximum flow. At that flow level, the marginal values per acre-foot appeared to be $27 for fishing, $7 for kayaking, and $5 for rafting, that is, a value of $39 total. In another study, Walsh, Auckerman and Milton (1980b) reported that leaving water in high mountain Colorado reservoirs for an additional 16.7 days in August is valued $61 per acre-foot over that period of time. Gibbons (1986) reported the estimated effect of flow reduction on anglers' visitation frequency in the Cache Valley in northern Utah, and derived a marginal value for water of zero for up to a 50 percent reduction in flow, and a marginal value of $127 per acre-foot for flows equal to 20 to 25 percent of 1982 peak level. Evidently, the value estimates for instream uses are low and are greater than zero during specific periods only. Corresponding capitalized values would range from $82 per acre-foot to $2,079 per acre-foot.

2.2.5 Implications

Published estimates of water values display great variation, not only among different uses, but also within each type of use. Similarly, and although the water value estimates reported here are not numerous enough to show any trend, water values within each particular use can be expected to fluctuate over time due to market and other factors. In other words, willingness-to-pay for water in each particular use follows a dynamic evolution, because the demand function relies on factors that are dynamic themselves (e.g., economic, social, climatic factors). The existence of structural value differentials among uses together with water value volatility over time leads to market development and at the same time allows prices to fluctuate according to market pressures. The next section reviews market and other factors that are hypothesized to affect water right prices and market activity.

2.3 Previous water right price-determinant studies

Few studies have addressed water right price determinant identification through the use of statistical tools. However, several publications have focused on the presumed benefits of water right markets and possible variables that may influence market activity and water right prices. This section reviews the literature on this subject.

Markets for water rights have been proposed by economists, politicians, environmental groups and government agencies (Michelsen, 1988; Gottlieb and Wiley, 1987). Many publications and conferences have focused on the virtues and vices of water markets (Michelsen and Young, 1993; Anderson and Turner, 1993; National Research Council, 1992; Howe *et al.*, 1986; Shupe *et al.*, 1989; Wahl and Osterhoudt, 1986). Although these publications advocate markets as an efficient way to allocate and use water, and at the same time to reduce economic and environmental costs, few studies have examined actual markets and market prices.

Khoshakhlagh *et al.* (1977) developed a three-equation model to forecast water right prices in the Rio Grande basin in New Mexico, each equation corresponding to one of the three major uses: agricultural, municipal and industrial uses. Each equation described the demand for water as being a function of both the price of water (endogenous variable) and a set of exogenous variables. The model was then solved simultaneously to yield a forecast price for water. Several of the determinants identified in the previous section appeared as exogenous variables, such as :

- population,
- per capita income,
- a climatic variable, here summer temperatures, and
- total agricultural output was used instead of the output per acre.

Although production values have been suggested for use in determining water right prices, they do not seem to adequately explain observed market transfer price levels and trends. Gardner and Miller (1983) constructed a model for the Colorado-Big Thompson market to test whether water right prices could be predicted by the returns on irrigation water (residual valuation method). They found that from 1961 to

1969, irrigation water's marginal values could adequately explain water right price levels. However, market prices rose sharply during the next decade, skyrocketing in 1980 to about $6,000 per acre-foot (1992 dollars) diverging significantly from the agricultural water marginal values. They attributed this "unexplained" part of water right behavior to a speculative element, whose existence was allowed by the value differential between municipal and agricultural uses. Based on a computed internal rate of return, they concluded that the 1980 price was very close to the municipal value of water (maximum willingness-to-pay).

A recent study by Colby *et al.* (1993) on water right price dispersion attributed price differentials to the water right characteristics, the institutional constraints, the physical transferability of water and the balance of power between sellers and purchasers. The significance of this last criterion supports the consideration of the buyer type (or the relative importance of municipal buyers every year) in our long-term analysis.

Speculation in water right markets has been discouraged by laws, institutions and economic disincentives (transaction costs), and is often ignored in traditional economic analyses. However, there is some evidence that speculation may affect and even be a leading factor in trends of water right prices. Both the Water Market Update (April 1987) and the National Research Council (1992) suggest that water rights are being used as investment commodities, and that speculative pressure can cause market prices to fluctuate widely. *The Water Exchange Information Service*, a subscription service to advertise and sell water rights was created in Denver in 1986.

Some brokers specialize in water transactions (e.g., Harrison Resources, Inc., Fort Collins, CO). Investment companies have been established that make speculative investments in water rights. For instance, Western Water Rights, Inc. decided to develop a portfolio of water rights along the Colorado Front Range for $35 million (*Water Market Update*, January 1987). All this suggests that water rights are increasingly regarded as investment assets, able to generate a profit. Therefore, the potential for speculative behavior in water right transfers needs to be accounted for in this study. Economic theory can help understand and model such behavior.

2.4 On the importance of expectations

Market participants' expectations of future price evolution is another factor that probably influences today's willingness-to-pay for water rights. This expectational component of price determination is likely to be based on the evolution of the demand, supply and other factors and a general perception of what the future will be. Anticipation behavior is directly related to speculation.

Given the potential influence of market participants' anticipations and the resulting opportunity for speculative behavior, a theoretical framework that can help to explain and model the decision-making process in water right markets is presented. The following section introduces the extensive literature on rational expectations and investment theory that has been applied successfully to the securities market (stocks and bonds).

<u>2.5 Determinant-price-relationships: the contribution of economic theory</u>

2.5.0 Introduction

Classical economics, which dominated economic thought in the first part of this century, is built upon two premises. The basic premise, upon which most economists agree, is that economic agents optimize, i.e., they seek to maximize expected profits or expected utility within the limitations of technologies and incomes available to them. The second premise stating that markets clear, is more controversial, and actually led all of the early classical models to fail, especially during the Great Depression (Willes, 1980).

The Keynesian theory was then adopted as a revolutionary alternative. It deliberately rejected the classical premises about the behavior of individuals and markets, replacing them by premises about the behavior of aggregates, such as the general price level and total unemployment (Buchholz, 1990). Keynes' economic theory has prevailed since the 1930's both for policy making and economic modeling. However, the 1970's witnessed the first major failings of conventional models that could not explain the simultaneous growth in inflation and unemployment, and at the same time saw more economists formulate critiques about Keynesian theory's inconsistencies. The move was started toward the counterrevolution of the rational expectations theory, viewed by many as a "new classical" school, since it rehabilitates a few well-established classical principles (Wallis, 1988).

2.5.1 Rational expectations

The rational expectations doctrine was first introduced by Muth (1961), although it was not until almost a decade later that it started to influence economic discussions. Muth's theory is based on the assumption that all economic agents formulate their expectations rationally, i.e., not only on the basis of what they have observed in the past but also in the light of all current information and knowledge available to them. Economic agents incorporate this information into a model of the economy which they believe is accurate, in order to generate a prediction (Shaw, 1984). rational expectations developed partly as a reaction against alternative specifications of expectation formation that produced inconsistent results in Keynesian models and that have been characterized as nonrational (Willes, 1980). The first of these is the static, or "naive" expectation thesis, which predicts next period's value for an economic variable by just considering its current value:

$$P^*_{t+1} = P_t \tag{2}$$

where Pt is the current price and P^*_{t+1} represents the expected price in period t+1, formulated in period t. However, this simplistic representation of price expectations ignores too many other influences. "The static expectation individual not only suffers from myopia but also from an extreme form of amnesia" (Shaw, 1984). A second alternative thesis is the one of adaptive expectations which is essentially extrapolative. Such expectations are derived as a weighted average of past observations. The merit of this approach is that the expectations are easy to incorporate into a mathematical model:

$$P^*_{t+1} = \sum_{j=0}^{\infty} w_j \, P_{t-j} \qquad (3)$$

$$with \quad w_j = \beta(1-\beta)^j, \quad 0<\beta<1$$

where P is the variable under investigation,

P^*_{t+1} is the expected value of X in year t+1, formulated in year t,

w_j is a weight factor which declines as j (time index) increases.

The rational expectations hypothesis is simply the extension of the rationality hypothesis to expectations (Guesnerie, 1992) and, taken literally, nothing more than a procedure for economic modeling. However, the rational expectations doctrine is based upon classical economics premises that individuals optimize and that markets clear, using rational expectations *per se* only as one assumption. "An economy in motion is best modeled by having agents change their decisions when the available information changes. This is what rational expectations models try to accomplish and what Keynesian models forget" (Willes,1980).

However, the assumption that markets clear and that economic agents immediately respond to new information have raised many questions and is still controversial. Consequently, while opinions are somewhat diverse concerning macroeconomic modeling, most economists recognize the merits of the rational expectations theory when applied to microeconomics and investment markets, e.g., the stock market (Buchholz, 1990). The reason is that most markets for labor goods and services are both complex and rigid, whereas investment markets are usually more efficient (e.g., low transaction costs) and more liquid (one can buy and sell easily). Therefore, investors' behavior can evolve with their own expectations, when information they receive is changing, and that justifies the quasi-consensus on the validity of rational expectations theory for modeling investment markets. According to Guesnerie (1992), rational expectations are based on two justifications : the *evolutive* process, which refers to learning by experience from the repetition of situations, and the *eductive* process, which involves the mental activity of "forecasting the forecasts of others."

Rational expectations have two essential properties (Blake, 1991). The first property is that they are an efficient method of expectations formation. This implies that rational expectations depend both on the model used to specify the economic system and on the information set used by economic participants. However, there are different degrees of efficiency corresponding to different models and information sets (Fama, 1970). "Strong-form efficiency" corresponds to a complete model and a full information set (i.e., all currently known information, including inside information). "Semi-strong-form efficiency" relates to a complete model and all publicly known information. "Weak-form efficiency" corresponds to an incomplete model and partial information set (i.e., involving only current and lagged values of the variable being predicted).

The second property of rational expectations is that they are consistent with, and generated by, the underlying economic model (for instance, the restricted reduced form for an endogenous variable).

This suggests that the rational expectations theory can appropriately serve as the basis to our analysis. Water right price-determinant relationships will be best modeled using a structural econometric model - which we believe is an accurate representation of the true model - and an information set that is available to everyone (semi-strong-form efficiency in Fama's words).

2.5.2 Speculation

The price of an asset, in a perfectly competitive market, should theoretically be equal to its market fundamentals, or the sum of discounted expected returns to be generated from the investment in this asset (standard efficient market model). To show this, let us consider the simple arbitrage relationship (West, 1987):

$$P_t = fE(P_{t+1} + d_t) \mid I_t \tag{5}$$

Where: P_t is the real asset price at the beginning of period t,

P_{t+1} is the asset price at beginning of period t+1,

f is the ex ante real discount factor (f= 1/(1+r)),

E denotes mathematical expectations (assumed to be linear projections),

d_t the real return earned from the asset during the whole period t,

and I_t information common to traders in period t. I_t is assumed to incorporate, at a minimum, current and past returns, and other variables that are useful in forecasting returns to the resource.

In this relationship, the current price P_t is equal to the discounted sum of expected annual returns and expected resale value, if any, in the following period. For reasons of simplicity, this relationship was limited to a one-period interval. It can be recursively generalized to get:

$$P_t = \sum_{i=0}^{n} f^i Ed_{t+i} \mid I_t + f^n EP_{t+n} \mid I_t \tag{6}$$

where the time period is extended to n intervals (t+n being the time of resale). At the limit, when n is very large, the discount factor $f^n = 1/(1+r)^n$ tends toward zero. Therefore:

$$\lim_{n \to \infty} f^n EP_{t+n} \mid I_t = 0 \tag{7}$$

If this condition, called transversality condition, holds, then the price of an asset is equal to the sum of the discounted benefits to be earned in the infinite future:

$$P_t = P_t^* \quad where \quad P_t^* = \sum_{i=0}^{\infty} f^i Ed_{t+i} \mid I_t \tag{8}$$

P^*_t is the unique forward solution to (8) as long as the transversality condition holds. But if this condition fails, there is a family of solutions to (8) (Shiller, 1978). Any P_t that satisfies:

$$P_t = P_t^* + b_t, \qquad Eb_t \mid I_{t-1} = f^{-1} b_{t-1} \tag{9}$$

where $b_t > 0$ and $f^{-1} = 1 + r$

is also a solution to (6). By definition, b_t is a speculative bubble, an otherwise extraneous event that affects asset prices (or stock prices) because everyone has similar expectations.

Camerer (1989) reviewed the literature on price bubbles and proposed the following classification for bubbles.

. **Growing bubbles** are typically constant terms, growing with time, and compatible with the rational expectations theory (Blanchard and Watson, 1982; Tirole, 1982, 1985) if markets are not limited by asset life or number of traders.

. **Fads** refer to mean-reverting deviations from intrinsic value, resulting from social or psychological factors such as those responsible for fashions in politics, entertainment or consumption.

. **Information bubbles** are typically of limited amplitude and are caused by imperfectly integrated information in market prices or by differences among agents' information sets.

Given that water rights are perpetual, that their markets are probably disconnected from fashions and that their prices can be highly variable, the most relevant category to water right markets is that of growing speculative bubbles. Going back to equation (6), the equilibrium condition will be satisfied as long as the bubble in time t equals the expected discounted bubble in time t+1 (Camerer, 1989) :

$$b_t = fE(b_{t+1}), \quad \text{that is,} \quad b_{t+1} = f^{-1}b_t + z_t \qquad \textbf{(10)}$$

Where z_t is a random term with zero mean and no autocorrelation.

Price bubbles of this sort grow every period at a rate equal to or greater than the discount rate, because they must provide some return to justify participation in the speculative pressure. Moreover, Blanchard and Watson (1982) showed that speculative bubbles are usually explosive and that they can exist even though rational agents know they will eventually burst.

On the other hand, the bubble component of an asset's price can never be negative, since then bubble growth would yield negative prices. Negative bubbles abort even before they start due to market participants' anticipation (Camerer, 1987).

Price bubbles are susceptible to develop if the following conditions exist (Tirole, 1985) :

- assets are durable - bubbles rely on expected resale value;
- assets are scarce - an asset easy to produce or supply if a bubble appears will drive prices down and burst the bubble;
- the asset market is active; and
- a common belief exists that a bubble is developing and will continue to grow.

The development of speculative bubbles is also supported by a set of experimental asset spot markets set up by Smith *et al.* (1988). They found that in fourteen out of twenty-two experiments, price increases were observed that were well above the intrinsic dividend value, thus forming price bubbles that would crash in the last few periods of the experiment. The probability of speculative bubble development was reduced, but not eliminated, when the market involved experienced traders.

Finally, an important contribution in explaining investors' behavior under uncertainty was made by Scharfstein and Stein (1990). They argue that under certain circumstances there are forces that lead to herd behavior in investment. This means that a manager will ignore his own private information and mimic other managers' decisions, simply because he believes they cannot be all wrong or is concerned about his reputation. Herd behavior can be expected to affect the course of resource market prices, particularly in periods of speculation.

To summarize, speculative bubbles appear in asset trading whenever the asset price diverges significantly from the discounted net present value of the stream of returns to be earned from the investment. In other words, rational agents are willing to pay more for an asset than fundamentals justify if they expect the price to continue to rise in the future. In this case, today's price is a bargain if they decide to hold the asset, or they can resell it at a profit (Gilles and Leroy, 1992). This situation results in a selffulfilling overreaction of the market at some points in time. Given the high variability of prices observed on some water right markets, it is interesting to consider the potential presence of speculative bubbles in water right price series.

CHAPTER THREE: METHODOLOGY

3.0 Introduction

The purpose of this chapter is to present the hypotheses to be tested in this analysis, to identify the potential water right price determinants, and to develop an econometric model. Economic theory will be integrated to identify the factors hypothesized to influence the level and trend of market equilibrium. The general model is selected from the rational expectations literature and adapted to our problem. The final model integrates the theoretical elements developed in Chapter Two to best represent the investment decision process.

3.1 Hypotheses

An extensive literature suggests that, as more water is being used outside agriculture, the irrigation value of water no longer explains the level and fluctuation of water right market prices. Together with a production value component, the price of a water right now contains a second element, whose amplitude and evolution are determined by market participants' anticipations. The existence of this second element on a permanent basis constitutes our primary hypothesis.

The second hypothesis is that water right prices can be successfully predicted through the use of a set of variables that reflect the socio-economic, market and hydrologic conditions, if economic agents' expectations are also incorporated into the model to account for potential speculative pressures.

3.2 Potential water right price determinants

3.2.1 A water reallocation model

A water right reallocation (transfer) model is used to illustrate the effect of economic and market factors on water right prices and market activity. Theoretically, demand and supply of commodities influence both market activity and transaction prices. Consequently, the forces that influence the demand and the supply of water rights are the primary factors that we want to identify as price determinants. A reallocation market for water can be graphically represented as in Figure 3-1.

A Reallocation Market for Water Rights

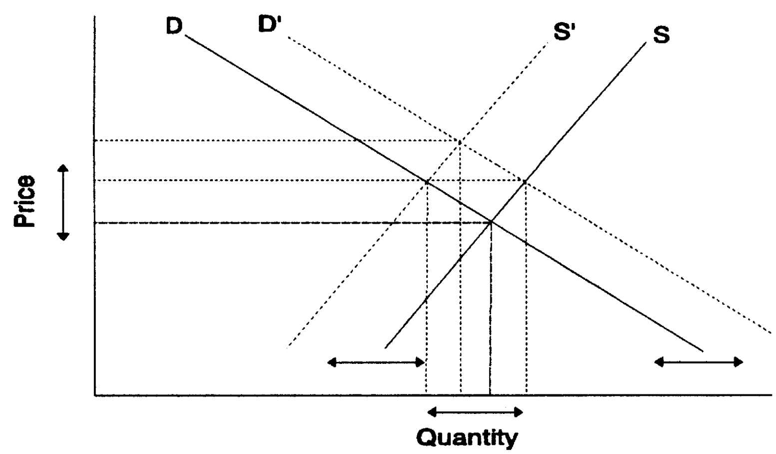


Figure 3-1

This graph shows the effects on price and quantity demanded of separate or simultaneous shifts in demand and supply. Water is considered as a normal good, which is reflected in the downward sloping demand curve and upward sloping supply curve. Under this assumption, the case where both price and quantity demanded increase at the same time is when the demand curve shifts to the right, or increases. However, the consequences of a demand shift can be altered by a shift in the supply schedule. It is the position and movement of the equilibrium point, i.e. the intersection of demand and supply, that is investigated in this study.

As mentioned earlier, three premises must hold in order for water right markets to develop. In this discussion, we assume that all water rights are fully appropriated, the demand for water is growing, and legal institutions are oriented toward market transfer development.

Note that we are dealing with the demand and supply of water rights for purposes of market trading only, not with total demand and supply as illustrated in Figures 2-1 and 2-2. Hirshleifer (1984) uses the terms transaction demand and transaction supply in this case, as opposed to full demand and full supply in the global setting. The transaction supply curve, unlike the full supply curve, is not completely inelastic. In other words, in a 'transaction' market, the willingness-to-sell of water right holders can be assumed to be somewhat responsive to price changes.

It is important to distinguish water right price dispersion, which is the variability at one point in time, of prices of different water rights with different characteristics, from the long term price variation of a homogeneous commodity over time. Colby *et al.* (1993) studied water right price dispersion in New Mexico, and related it to the commodity's heterogeneity (priority date, geographic flexibility), the importance of search and information costs, and the number and size of market participants. This study focuses on temporal price evolution and assumes that we are dealing with homogeneous water rights, as is the case with mutual ditch and irrigation companies.

Microeconomic theory suggests that price is an exogenous variable when studying quantity supplied and quantity demanded separately. Exogenous means determined outside the system under investigation whereas endogenous means determined inside the system. When demand and supply are considered simultaneously, price becomes an endogenous variable of the market system (Gisser, 1981). The purpose of this study being to explain price movements over time, the model form that is considered is a reduced-form model of a water right market system, as opposed to structural-form models intended to explain the formation of demand and supply. It is the effect of exogenous factors on the movement of equilibrium over time that is of interest. As underscored by Gisser (1981): "In the supply-demand model of perfect competition, changes in exogenous variables lead to either demand shifts or supply shifts or both; the result is a change in the endogenous variables price and quantity." Therefore, let us now identify the exogenous factors potentially responsible for demand and/or supply shifts, leading to changes in price and market activity over time.

3.2.2 Demand shifters

As previously discussed, the use or production value of water varies considerably depending on the type of use. Factors that influence the production or use value of water may help to explain changes in the demand (thus, the willingness-to-pay) for water rights. Given that most transactions involve transfers of water from agricultural to municipal and industrial uses, agricultural water right owners are considered as the main suppliers and municipalities and industries as the main demanders for water. Therefore, the willingness-to-pay for water in irrigation is viewed as an opportunity cost and is considered below in the supply shifters.

Municipal water demand is growing in importance and in many areas is the main water purchaser (Saliba and Bush, 1987; National Research Council, 1992). The municipal sector (primarily water utilities) is responsible for providing a growing urban population with sufficient water. Purchase of agricultural water rights is often the least-cost alternative for providing additional water supplies for growing municipal demand and for drought protection. Municipal demand refers to consumer demand theory, which suggests that demand shifts come from changes in population, income, prices of other goods (complements and substitutes) and changes in tastes, lifestyles, etc. Young & Gray (1972) and Khoshakhlagh *et al.* (1977) proposed that per capita water consumption increases with per capita income. Consequently, population and per capita income may be used as indicators of urban water demand. Another indicator of the growth in municipal water demand may be provided by the number of housing construction starts (which also relates to inflation, interest rates, confidence in the future, etc.). Finally, given that willingness-to-pay for water is higher on average in the municipal than in the agricultural sector, the effect of a long drought period on municipal purchases of water rights seems worth investigating. For example, if population - thus, the demand - is anticipated to keep growing in the future, a municipality may purchase more water in a dry period to ensure water supply, knowing that this additional water will be needed some time in the future, and that it can be rented back to irrigators in the meanwhile. To summarize, changes in population, per capita income, building permits and rainfall are hypothesized to be accurate indicators of municipal water demand evolution.

The industrial demand for water is another application of factor demand theory. Shifts in the aggregate demand for industrial water are theoretically induced by changes in other input costs or in the elasticity of demand for the final product. Globally, changes in the level of economic activity can be expected to encompass the shifts in industrial demand for water. In the absence of a better proxy, municipal demand indicators (e.g., population and per capita income) will be used to measure the contribution of industrial water demand to water right price variation.

The effect of instream water demand on water right prices is more difficult to assess. Instream water demand is typically not accounted for in water right markets. As a result, this type of demand cannot be considered as a structural demand and, even though it exists, is not addressed in this study.

3.2.3 Supply shifters

Regional water supplies are typically fixed in the long run, but they can vary in the short run due to hydrologic conditions (precipitation, snowpack, etc.). The quantity of water available to individual water right holders at one point in time depends on the actual total availability of water within the region (precipitation, streamflow and reservoir storage) and the allocation priority of the water rights. Within this setting, the supply of water rights on the market (i.e., the transaction supply) is assumed to be a upward sloping curve; the higher the price, the more water owners would be willing to sell.

Since irrigated agriculture is the dominant water user and water right owner throughout most of the western United States, it seems reasonable to consider agricultural production and economic value measures (i.e., opportunity costs) as influencing the supply and price for water. Agricultural market conditions hypothesized to influence water right prices include: agricultural production and income (crop prices, yield, input costs); long run financial condition of farm enterprises; and ratio of urban-to-agricultural water right ownership.

Crop yields, selling price and input costs - and, therefore, the net revenue from crops - can be expected to vary, sometimes considerably, from year to year. In fact, several consecutive "bad" years can tremendously affect farms' financial situation, and lead to voluntary water right sales for cash flow recovery, or at the extreme, to foreclosures and bankruptcies. Basically, the price received by farmers for irrigated crops or, better, the net revenue per acre, should constitute good indicators of water supply evolution. Also, a measure of the farming sector's financial stress (e.g., debt-to-asset ratio) or the number of farm foreclosures may help explain the amount of water rights available on the market.

On a long run basis, one more variable needs to be considered: the ratio of urban-to-agricultural water right ownership. Effectively, as water is being transferred away from agriculture, the less water rights remaining in the farm sector, the tighter the market and the higher the price can be expected to be for water rights.

Another important, but previously untested hypothesis is the influence that increases or reductions in the regional water supply will have on water right prices. Available water resources may be increased in the region through interbasin imports, construction of new storage facilities, and possibly through improvements in water use efficiency. Theoretically, these would tend to reduce the price of existing water rights, reflecting a rightward shift in the supply curve. On the other hand, exports of water from the region or a reduction in available water rights (e.g., reserved water right allocations) would be assumed to cause a leftward shift in the supply curve for water rights.

3.2.4 Speculative factors

Water rights may have value in addition to their current use or production value. They constitute assets which offer other attributes like a value storage function, for example. Also, market participants formulate expectations about the future course of the regional economy which may affect their current willingness-to-pay for water.

Water rights as assets

Water rights can be regarded as real pieces of property, like land, housing and other assets. Therefore, the demand for water rights can change due to factors affecting the cost of obtaining them or the value they carry over time. Real interest rates (i.e., nominal interest rates corrected for inflation) are a key determinant in investment decisions since they reflect the real cost of money at the time the investment is made. Also, the inflation rate provides an incentive to own assets for their value storage properties, or because of a tax reduction advantage (Sheffrin, 1983). Therefore, interest and inflation rates can play the role of demand shifters in water right markets.

Market participants' anticipations

Anticipated changes in demand, supply and other factors also may influence the price path of water rights. Expectations regarding future population growth, economic growth, inflation and interest rates, regional water supply or changes in institutions can be expected to affect willingness-to-pay for water. These expectational forces can cause shifts in either the demand or the supply curves.

3.2.5 Market dominance

So far, we have identified the variables likely to influence the quantitative supply and demand for water rights, which in turn determine market price level. However, the qualitative aspects of supply and demand can also be relevant to our analysis. Effectively, the type of buyer and seller can be significant because of different use values, negotiating power, and dominance in a market. The type of buyer and seller may influence market prices because of the willingness-to-pay associated with each use. Furthermore, the negotiating power of market participants may well depend on their type of use and level of activity in the market. Since we know that most traded water rights originate from agriculture, the type of seller is quasi-constant and therefore does not provide much insight on price movements. However, dominance of one buyer type over another may be reflected in the market equilibrium or price. For instance, municipal and industrial buyers may be expected to raise bids for water rights and their dominance in the market would result in higher prices. These market factors may be accounted for through the number of transactions by buyer type or the relative proportion of each buyer category.

3.2.6 Institutional factors

Given the importance of institutions in water management, it is appropriate to consider the role they play in water right price evolution. The priority date of the right itself, the importance of legislative constraints and transaction costs, the existence of features or equipment enabling the transfer to be physically done all affect the attractiveness of a water right. Also, regulations relaxing or restricting the transfer of water rights can shift the transaction supply curve respectively to the right or to the left.

There are two ways of dealing with these price-influencing factors. The first way is to incorporate them in the analysis and try to determine their relative influence. This approach may be useful when studying water right price dispersion, usually on a large geographical scale.

The second way is to focus on specific regional markets, where water rights have the same characteristics (priority date, reliability, yield, etc.) and are subject to the same legal processes so that they are directly comparable. Ideal settings of this sort are provided by irrigation companies or water conservancy districts. Basically, original rights are held by the company or district which issue uniform shares that can be bought, held, sold or leased by individual users, municipalities, etc. The advantage of studying such markets is that it is possible to isolate the effects of the economic environment on price variation, as well as to compare water rights to other commodities.

3.2.7 Summary

The key factors hypothesized to influence water right price behavior over time are summarized below, as well as their respective expected effect on water right prices (i.e., signs expected in the econometric analysis; + complementary influence or - inverse influence):

Demand:	- regional population (+)
	- per capita income (+)
	- housing construction starts (+)
	- rainfall or drought conditions in several consecutive years (-)
Supply:	- net revenue from irrigated crops or crop prices and yield (+)
	- farms debt-to-asset ratio (-)
	- farm foreclosures (-)
	- ratio of agricultural-to-urban holders (-)

- addition or withdrawal of water supplies (-)

Speculation:
- inflation (+)
- real interest rate (-)
- market participants' expectations about future evolution of water right prices due to the perceived economic, social and market conditions (+)

Market:
- relative acquisitions made by municipal/industrial sectors (+)
- market activity (number of annual transactions) (+).

Apart from these price fluctuation determinants, a decision-maker involved in water management also will consider the specific characteristics of a water right (e.g., priority date, long-term yield, transferability, etc.) when comparing price patterns for different water rights. Again, these characteristics are fixed over time for a given water right, and therefore are not considered in this analysis.

3.3 Model development

3.3.1 Selection of a general type of model

The proposed hypotheses will be tested using a rational expectations (RE) model in order to incorporate market participants' anticipations as well as traditional demand and supply variables. A review of the specific literature reveals the existence of a plethora of studies and a variety of approaches. Fortunately, Blake (1991) surveyed and categorized most of the published methodologies using a simple classification: linear and non-linear models, incorporating present-valued or future-valued expectations. Linear models have, by far, been used the most in the past. The major reason is that non-linear models are more complicated models to solve and estimate. They do not necessarily have a solution, and when they do, reaching a stable solution is sometimes very difficult (Neter *et al.*, 1989). According to Blake's classification, and given the nature of our problem, we decided to adopt an approach that fits into the class of linear models involving future expectations. The linearity in variables and parameters was retained to avoid estimation problems and to keep the interpretation of the results at a more accessible level.

The motivation for incorporating future-valued instead of present-valued expectations comes from the fact that future-valued expectations models have been successfully applied to other investment situations, like the stock, bond, and housing markets (Blake, 1991). A second motivation is that expectations of future values of endogenous variables, such as expected inflation or expected price movements, often play an important part in explaining current behavior (Wallis, 1988). Therefore, future-valued RE models can fully account for speculative pressures: what people expect the price to be in the future is a major factor leading to speculative behavior. Following this approach, our hypotheses were examined through an econometric model emphasizing the long term trend of water right prices using a general model of the form:

$$P_t = a + bP^*_{t+1} + cX_t + u_t \tag{11}$$

$$where \quad P^*_{t+1} = E_t(P_{t+1}) = E(P_{t+1} \mid I_t)$$

where P_t is the price of a water right in year t,

a, b, c are regression coefficients,

X_t is a set of exogenous variables, possibly lagged,

u_t is the error term,

P^*_{t+1} is the expected value of P in year t+1, formulated in year t, conditional on I_t, the information set available at time t, which is:

$I_t = (X_t, \ldots, X_{t-n}, P_{t-1}, P_t, \ldots, P_{t-n})$,

E denotes mathematical expectations, and

n is the number of years included in the information set.

Furthermore, rational expectations imply that economic agents produce accurate forecasts of the endogenous variable:

$$P_{t+1} = P^*_{t+1} + v_{t+1} \tag{12}$$

In other words, the real price and its expected value formulated one year earlier are equivalent, apart from a white-noise forecast error v_{t+1}.

The objective of this model is to best integrate the true decision-making process in water right investment. An asset's price in year t is hypothesized to be determined by what people expect the price to be in year t+1, together with the level and evolution of appropriate exogenous variables. However, models involving future-valued expectations of the endogenous variable are more complicated to estimate and identify than models based upon current-valued RE. There are four types of solutions for linear models involving future REs: globally stable, unstable, saddle-point and regular solutions (Begg, 1982). The first three can yield non-unique solutions whereas the fourth involves a natural unique solution. The type of solution for the model depends on its specification.

Unless a survey is done every year, the true expectations generated by economic agents are unknown. Yet, in order for the model's identification to be assessed and for the model to be correctly specified and estimated, the expectations of the endogenous variable have to be taken into account by the model (Blake, 1991). There are two ways of doing this (Wickens, 1982). The first way is to use the substitution method, or method of 'undetermined coefficients,' developed by Whiteman (1983), which replaces the unobserved RE variable with forecasts generated by a moving-average process. A slightly different formulation (different composite error term) of the Whiteman substitution method was introduced by Chow (1983) for the same purpose of imposing a solution on the RE variable. The major drawback of the substitution method is that it can yield multiple and unstable solutions, and sometimes implies non-linearity in the parameters (Blake, 1991). Moreover, this method involves arbitrary constraints on the moving-average process such as stationarity of the RE variable which is not desirable in this study of highly fluctuating water right prices.

The second way of imposing a solution on the RE variable(s) is the Errors-in-Variables Method (EVM) which replaces the unobserved RE variable(s) (unobserved at time t) with their actual, post-observed values. The EVM was first introduced by Mills (1962) under the name of implicit expectations. Subsequent examples of utilization of the EVM in rational expectations models include McCallum (1976) in a model of the demand for labor, Hansen and Singleton (1982) in a study of stock prices and Cumby *et al.* (1983) in a macroeconomic model of the United States. The principle is to replace P^*_{t+1} and add a second equation to explain P_{t+1}, thereby creating the two-equation system:

$$\begin{aligned} P_t &= a + bP_{t+1} + cX_t + w_t \\ P_{t+1} &= d + \sum_{i=1}^{n} e_i P_{t-i} + \sum_{j=0}^{n} f_j X_{t-j} + v_{t+1} \end{aligned} \tag{13}$$

where $w_t = u_t + b(P^*_{t+1} - P_{t+1}) = u_t - bv_{t+1}$,

v_{t+1} is a forecast error with zero mean,

a, b, c, d, e, f are regression coefficients,

i and j are time indices,

and all other terms are defined as above.

If serial correlation is absent, this model can be consistently estimated by instrumental-variables techniques, with the instrument for P_{t+1} being the fitted value from the least squares estimation of the second equation in (13). Therefore, by construction, w_t will be uncorrelated with the elements of the information set I_t and with the instrument for P_{t+1}. With the EVM, all parameters are identified. The advantage of this technique is that it reduces the identification and estimation problems usually associated with rational expectations models. It imposes explicitly a stable and unique solution since the expected value is replaced by the actual value plus an orthogonal error (Wickens, 1982).

In the absence of serial correlation, therefore, the preferred estimation technique is the Three-Stage Least Squares (3SLS). This technique involves the application of generalized least squares estimation to the system of equations, after both equations have been estimated by a Two-Stage Least Sqares (2SLS). In the first stage of the process, all endogenous variables (here P_t and P_{t+1}) are regressed using Ordinary Least Squares (OLS) on all predetermined variables in the system (reduced form model). The second stage uses the first stage fitted values as instruments to estimate the complete equations in the model. The third and final stage applies generalized least squares which accounts for cross-equation correlation among error terms. The motivation for selecting 3SLS is that it yields more efficient parameter estimates than 2SLS if cross-equation correlation is present (Pindyck and Rubinfeld, 1991). Since in our model, both equations contain the same left-hand side variable with only one period difference (i.e., P_t and P_{t+1}), the error terms may well be correlated across equations, thus justifying the use of 3SLS. If serial correlation is present, however, Two-Step Two-Stage Least Squares (2S2SLS) (Cumby *et al.*, 1983) or Generalized Two-Stage Least Squares (G2SLS) (Blake, 1991) have been shown to produce efficient and consistent estimates.

3.3.2 The model developed for the analysis

Having selected the general form of model, it needed to be specifically adapted to this particular analysis. Instead of incorporating the same information set in both equations, it seemed more appropriate to differentiate the equations in terms of structure and information content. Therefore, it was decided to split the information set into two categories: one group containing all variables thought to be slowly reverting and to have a long-term effect on water right prices and the second group containing the short-term effect variables. The group of long-term effect variables was incorporated in the equation that explains the future price expectation. Also, the history of these specific variables was important to integrate in the equation; the way this was done is described below. The second equation, involving P_t as the dependent variable, was then structured to capture the short-term (or annual) effect of the other variables together with the price expectation. With this structure, the future-valued expectation is based on the level and evolution of long-term, slowly reverting trend variables which are the only ones that can be accounted for in a forecasting process. In turn, the current price determination is based on the effect of the long-term variables through the fitted value of the price expectation, plus the short-term effect of less predictable variables.

An important decision remained regarding the type of relationship between past values of long-term variables and the dependent expectational variable. In other words, we had to select an appropriate lag structure. The geometrically distributed lag scheme, also called Koyck geometric lag (Pokorny, 1987), was first considered for its simplicity and its ability to integrate all past observations of the exogenous variables. However, this lag structure was unusable in our model for two reasons. The first reason is that the price expectation is formulated not only as a function of a set of exogenous variables and their history, but also of the price's own history, making the determination of the lag coefficient impossible. The second reason was the resulting presence of a P_t term in the price expectation equation. This P_t term would represent the actual values for P_t, not the fitted values computed from the other equation, therefore making any simultaneous estimation technique inadequate.

Another lag structure that was envisaged was an adaptation of the Koyck lag scheme suitable to our assumptions and model. In brief, it consisted of associating a geometrically declining factor to every exogenous variable for a defined number of years in the past. The problem of this technique was that it introduced non-linearity in the parameters, thus requiring non-linear estimation techniques with the drawbacks described earlier.

The retained lag structure was the polynomial distributed lag (PDL), introduced by Almon (1965). More flexible than the Koyck geometric lag for the functional form that generates the lag weights, the PDL requires that both the lag length and the functional form be specified *a priori*. The shape of the lag function is determined by the degree of the polynomial: a PDL of degree 1 is linear, a PDL of degree 2 is parabolic, etc. Given the time length of our analysis, it seemed reasonable to take into account five years of each explanatory variable's history: the current plus the four most recent years. A constraint was imposed during estimation so that the lag weight in year t-5 was equal to zero. By selecting a linear PDL with such a constraint, we were able to come up with a lag structure of linearly declining weights representing the decreasing influence of events on decision-makers as time goes by. The construction of the PDL is described below.

Let us consider a dependent variable, P_t, an independent variable, X, and assume a four-period lag as suggested above. Such a model can be written:

$$P_t = \alpha + \beta_0 X_t + \beta_1 X_{t-1} + \ldots + \beta_4 X_{t-4} + \varepsilon_t \quad (14)$$

If we then assume that the ß's are generated by a linear function, we can specify:

$$\beta_k = a_0 + a_1 k \quad (15)$$

where k is an index, which can take on any integer value between zero and four. From equation (15), successively substituting for k=0 to 4, we have:

$$\begin{aligned} \beta_0 &= a_0 \\ \beta_1 &= a_0 + a_1 \\ \beta_2 &= a_0 + 2a_1 \\ \beta_3 &= a_0 + 3a_1 \\ \beta_4 &= a_0 + 4a_1 \end{aligned} \quad (16)$$

Substituting for the ß's, equation (14) becomes:

$$\begin{aligned} P_t = \alpha + a_0 X_t + (a_0 + a_1) X_{t-1} + (a_0 + 2a_1) X_{t-2} \\ + (a_0 + 3a_1) X_{t-3} + (a_0 + 4a_1) X_{t-4} + \varepsilon_t \end{aligned} \quad (17)$$

Rewriting equation (17) by collecting all terms in a_0 and a_1, we have:

$$P_t = \alpha + a_0(X_t+X_{t-1}+X_{t-2}+X_{t-3}+X_{t-4}) + a_1(X_{t-1}+2X_{t-2}+3X_{t-3}+4X_{t-4}) + \varepsilon_t \quad (18)$$

Thus we can define two composite variables V_1 and V_2 as follows:

$$\begin{aligned} V_{1t} &= X_t + X_{t-1} + X_{t-2} + X_{t-3} + X_{t-4} \\ V_{2t} &= X_{t-1} + 2X_{t-2} + 3X_{t-3} + 4X_{t-4} \end{aligned} \quad (19)$$

Therefore, the model in equation (14), incorporating the assumption of linearity in equation (15), can be written as:

$$P_t = \alpha + a_0 V_{1t} + a_1 V_{2t} + \varepsilon_t \quad (20)$$

Thus, estimates of α, a_0 and a_1 are derived by regressing P_t on the composite variables V_{1t} and V_{2t}. Finally, estimates of the original ß's can be obtained by substituting the resulting values of a_0 and a_1 into equation set (16).

The linear constraint of the lag structure could be imposed during estimation in the following way:

$$\beta_5 = a_0 + 5a_1 = 0$$

The advantage of this structure is that it introduces only two variables per factor, independent of the number of lagged observations considered. This is particularly useful when the total number of observations in the data set is limited, as is often the case for water-related research. For the same reason, multicollinearity problems may be reduced with this lag structure. Finally, this PDL scheme (including the constraint on year t-5 during estimation) facilitates interpretation of the results.

Coefficients associated with an explanatory variable and its lagged values all have the same sign and the same level of significance. Consequently, the total contribution of each variable over time is distinctly given by the model.

In summary, it can be said that the efforts on the model development were oriented toward the specification of a model that adequately depicts the decision-making process. The final model is based on the rational expectations theory and incorporates a linear declining lag structure. Overall, it is designed to be flexible (i.e., easily adaptable to different water right markets) and produce straightforward results.

3.4 Testing for speculative bubbles

The existence of speculative bubbles has been tested for on various markets, using an array of different procedures. Direct tests were used by Flood and Garber (1980) and Burmeister and Wall (1982) on 1920's German hyperinflation data, leading to contradictory conclusions whether a speculative bubble was present. Meese (1986) and West (1987), using a different approach, found evidence of bubbles in dollar-mark and dollar-pound exchange rates, and the stock market, respectively. Indirect diagnostic tests have been used by Hamilton and Whiteman (1985), Diba and Grossman (1988) and Meese (1986), and were based on stationarity diagnostics (unit root and cointegration tests). Tegene and Kuchler (1990) used the same technique to detect the presence of a speculative bubble in farmland prices and rejected this hypothesis.

All of the examples reported here use a measure of market fundamentals, e.g. dividends for stocks, bonds and gold, land rents for farmland markets or a Cagan-type money demand model for the German hyperinflation. However, no information is available on the returns to be earned from investing in water rights for municipal use. As discussed above, municipal demand for water is the leading element in water transfers in the western United States. Without any available measure of water market fundamentals in municipal use, it is not possible to perform a rigorous test for the existence of speculative bubbles in water right market prices. Consequently, our analysis on speculative bubbles limits itself to recognizing the presence of the necessary conditions for a price bubble to develop (refer to Chapter Two), and to providing some insight through a descriptive analysis of the price series (performed in Chapter Six).

CHAPTER FOUR: THE CASE STUDY AREA

4.0 Introduction

This chapter introduces the geographic area under investigation, and presents the transfer mechanisms, water law and economic aspects that are characteristic of this area. The selected case study area is the Northern Colorado Water Conservancy District's water service area, located in the Colorado Front Range, in northeastern Colorado.

Several reasons motivated the selection of this area. First of all, it is representative of many western regions in its urbanization pattern, its agricultural diversity and its scarcity of water supplies. Second, under Colorado water law, as in most western states (except Arizona), water rights are not appurtenant to land and can be transferred separately. This flexibility facilitates water transfer development for both water rentals and permanent transfers. As an example of Colorado's water transfer development, MacDonnell (1990) reported an average of 85 annual applications for water right transfers filed in state water courts from 1975 to 1984. Because markets have developed in this area, historical information about market prices for water is more readily available. Most water rights in this region are held by irrigation companies, water districts or water service organizations. Thus, market participants actually own and trade shares from those institutions. These shares are often more transferable and more homogeneous commodities than are the original water rights.

Although pressure on scarce water resources has increased dramatically throughout the West, water transfers and markets are just beginning to be established in most other states. Therefore, historical information on transfers and prices is often too limited for study purposes. This is why it was decided to take advantage of Colorado's reputation for supporting well established and mature water markets.

4.1 The Colorado Front Range

The Colorado Front Range extends from Walsenburg in the south to Wellington in the north, along the east slope of the Rocky Mountains. About 80 percent of Colorado's population is concentrated in this area, totaling 2.7 million in 1989 (National Research Council, 1992). During the energy boom of the 1970's, the Colorado Front Range has been one of the fastest-growing regions in the United States, with a 2.5 percent annual growth from 1970 to 1980. Due to the concentration of population, most of the state's water marketing activity takes place in this area.

The Colorado Front Range relies primarily on mountain runoff for water supply. In order to meet the demand on the east slope, natural surface water supply is supplemented with water diverted from the west slope across the Continental Divide and with ground water. Transmountain diverted water originates from the upper Colorado River for the most part and from the North Platte River basin to a lesser extent, both on the west slope of the Continental Divide. Receiving watersheds are the South Platte River basin (Big Thompson, Poudre and South Platte Rivers) and the Arkansas River basin.

4.2 Colorado's economic characteristics

Given that water demand is hypothesized to be related to population, economic growth, and other market factors (among others), it is insightful to provide a description of Colorado's economy and its evolution.

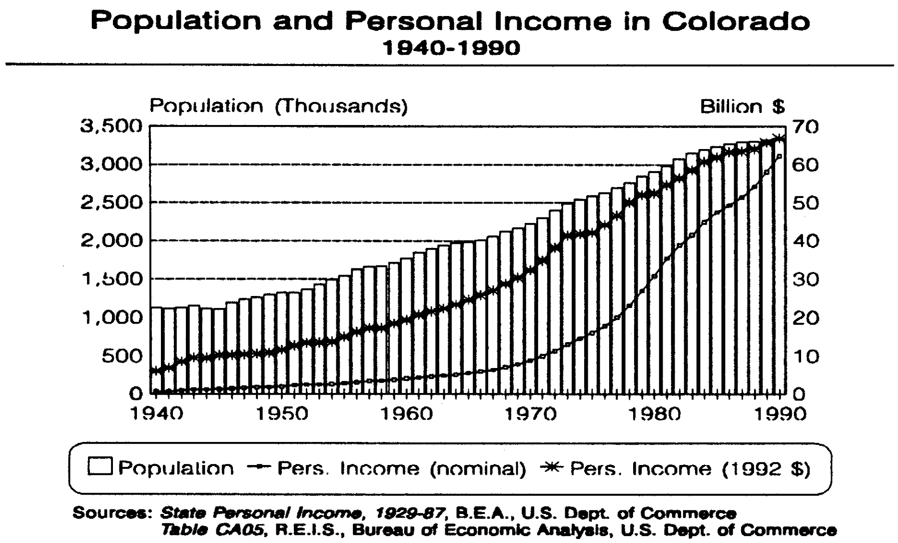
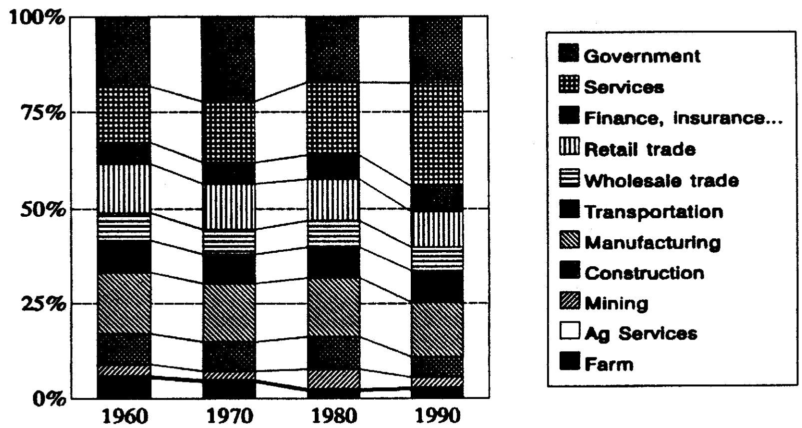


Figure 4-1

The state of Colorado has undergone profound changes in its economy over the past decades. As shown in figure 4-1, population increased threefold since 1940, and the total personal income (in constant terms) has followed the same trend. The annual increase in both population and personal income was highest during the 1960's and 1970's. While the already limited relative contribution of agriculture to the total personal income has been declining, that of services has increased importantly (Figure 4-2). Therefore, it seems normal that, as population grows and as more relative wealth is being created outside agriculture, more water is being demanded for

Major Sources of Personal Income for Colorado



Source: Table CA05, R.E.I.S., Bureau of Economic Analysis, U.S. Dept. of Commerce

Figure 4-2

municipal and industrial uses. Also noticeable is the 1970's energy boom, where crude oil prices increased and oil exploration was boosted following the worldwide oil crisis.

The economic characteristics described above suggest that pressure on Colorado water demand has increased over the past decades. Actually, trends in population and economic growth in the southwestern United States have raised the concern - particularly acute in the 1970's - about a potential future water shortage. This widespread concern may well have led to speculative behavior in water right markets.

4.3 Water law in Colorado[1]

Water law plays a crucial role in water transfer development and market activity. Water law regulates the allocation and distribution of water, establishes property rights to water, and usually determines whether water rights can be transferred. Moreover, transfers and market institutions are regulated under state law, which partly explains the variability of market activity among western states. Following is a general description of water law in Colorado.

The state of Colorado has adopted the prior appropriation doctrine to regulate water rights since 1876, date of its constitution. The prior appropriation system administers both surface water and ground water that is tributary to a surface stream. Two other categories of ground water follow different rules. In certain 'designated' basins, ground water is regulated by a modified appropriative system (conjunctive surface/ground water); and rights to the remaining nontributary ground water (usually deep aquifers) are based on ownership of the overlying land rather than appropriation.

Water law in Colorado, although complex, is oriented toward transfer development (MacDonnell, 1990). Water rights are considered as property rights, and are transferable in the same way as other property rights. Transfers with no change in location or use can be done without restriction. However, water right transfers are subject to public review when they involve changes in the point of diversion or in the type, place and time of use. A water judge is appointed for each of the state's seven

[1] Main sources for this section: MacDonnell, 1990; Radosevich, 1976.

administrative water districts by the Colorado Supreme Court. The role of the district courts is to carry out all hearings relating to each transfer, in order to implement the 'no-injury' rule; to avoid injury to other water rights, the transfer should not increase the depletion of the stream. In other words, only the consumptive part of a water right (total diversion minus return flows) can generally be transferred. Applications for water right transfers are usually adjudicated if the applicant can demonstrate that the change will not injuriously affect third parties, or that potential injuries can be adequately mitigated or compensated (Saliba and Bush, 1987). Colorado law also authorizes temporary loans and exchanges of water.

Furthermore, some institutional settings have been established in order to facilitate water transfers and address imported water and water supply organizations. Imported water, which refers to water conveyed into one basin from another basin, and non-tributary ground water both have a unique legal status. Since these waters are not considered native to the system, corresponding water rights can be used, reused or sold to extinction, regardless of return flow. For instance, if a water user owns a right to 100 acre-feet of imported water and if he can demonstrate to the water court that return flows amount to 40 percent of the diverted water, he has the right to use or sell the corresponding 60 acre-feet of water. Consequently, rights to imported water and ground water are highly transferable and active trading of these rights is actually taking place.

Various types of water supply organizations exist in Colorado. Most of these entities were originally established to provide water for irrigation purposes, although some of them are specifically oriented toward multi-purpose or municipal service. Mutual ditch and mutual reservoir companies manage most of Colorado irrigation water (MacDonnell, 1990). In these companies, individual water users own shares of stock which entitle them to receive a *pro rata* quantity of water. The priority of shareholders' rights may vary, and if so, usually according to different classes of stock (MacDonnell, 1990). Shares of stock are legally recognized as personal property and can be bought, sold or leased within the company boundaries without judicial review, provided that the transferee puts water to beneficial use. Sometimes, transfers may be subject to approval by the company's board of directors. If a transfer implies a change in the water right, it must be approved by the district water court, in order to implement the no-injury rule.

Irrigation districts were authorized by Colorado law in 1901 in response to the need for entities capable of financing large irrigation projects. They hold title to their water rights in trust and have the power to transfer them, usually after prior electorate approval. Irrigation districts can usually transfer water rights outside their boundaries and often can lease their surplus water within or outside their service areas.

Water conservancy districts were originally conceived to supply multi-purpose water originating from development projects constructed by the Federal Bureau of Reclamation. There are two conservancy districts in Colorado: the Northern Colorado Water Conservancy District and the Southern Colorado Water Conservancy District, both located in the Front Range area. Under Colorado law, districts are quasi-municipal corporations and political sub-divisions of the state. They are given broad authority to carry out their purpose and can tax all lands within their boundaries regardless of whether they receive water. A district's Board of Directors controls water allocation and water transfers within the district's service area. For a water transfer to be authorized, the transferee must demonstrate the beneficial character of the planned water use. Permanent transfers of water outside the district's boundaries are not allowed, but since 1989 water can be leased or exchanged for use outside the service area.

Water destined for municipal use, including commercial activities, is typically supplied by city water departments or special water districts. These entities can acquire water through appropriation, purchase, condemnation, or lease. Because of the growing municipal demand, they are allowed to hold more water than they immediately need and to lease the surplus outside their city limits.

Therefore, the complex water law in Colorado is oriented toward transfer development and the number of transfer applications filed to district water courts is quite important (MacDonnell, 1990). From 1975 to 1984, 858 applications for transfer were filed, excluding transfers involving changes in points of diversion only. Eighty percent of these applications were approved, 10 percent were withdrawn, only 1.3 percent (11 applications) were denied, and the remainder were still pending at the end of the study. However, the court decision process was rather long: 21 months on average.

Apart from these court-processed transfers, many transactions take place within water supply organizations. For the purpose of our study, we will now focus on the Colorado-Big Thompson transmountain diversion project, located in the northern part of the Colorado Front Range. This project has given rise to an established water market, in large part due to the relatively easy transferability of water within the district service area.

4.4 The Colorado - Big Thompson Project[2]

4.4.0 Introduction

The Colorado-Big Thompson (CBT) project was constructed by the U.S. Bureau of Reclamation to provide supplemental water supplies for agricultural, municipal and industrial uses in northeastern Colorado. Started in 1938 under a repayment contract between the United States and the Northern Colorado Water Conservancy District (NCWCD), it became operational in 1957. The purpose of the CBT project was - and still is - to provide supplemental water from the Upper Colorado River basin to offset the fluctuations in natural supply in the South Platte River basin. Physically, this is achieved by diverting West slope water across the Continental Divide through the Adams tunnel into the Big Thompson river on the East slope. The U.S. Bureau of Reclamation appropriated the project water rights through 1955 and 1966 decrees. The NCWCD is granted, by contract, the perpetual right to use all water made available by the construction and operation of the CBT project, provided it abides by the terms and conditions of the repayment contract.

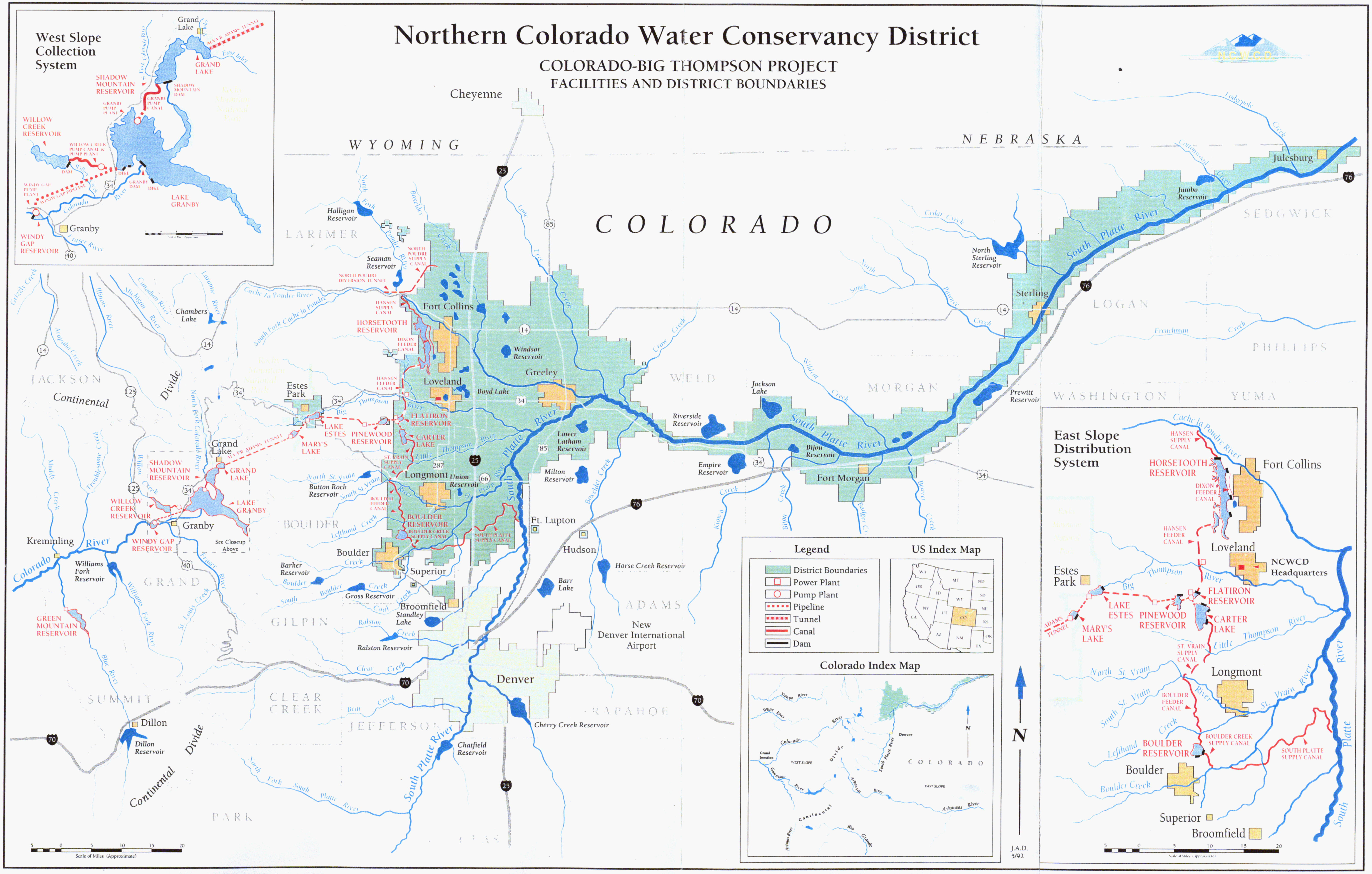
[2] Main sources for this section: Water Strategist, October 1990; Saliba and Bush, 1987.

The NCWCD includes the cities of Boulder, Estes Park, Fort Collins, Greeley, Longmont and Loveland and serves a population of over 460,000 (See map). It is governed by a board of twelve directors, appointed for staggered four-year terms by the presiding state district court of the four water districts located wholly or partly within the district service area. Water users obtain the right to use project water through allotment contracts signed with the district. There are four types of allotment contracts: class B (municipal), class C (irrigation district), Corporate Form (individuals, public or private corporations, mutual ditch companies and water user associations) and class D (allotments to lands for irrigation use). The main characteristics of the CBT project operation are described below.

4.4.1 Characteristics of the CBT project[3]

Rights to CBT water are represented by 310,000 shares or "acre-foot units." Each share or unit represents an equal claim on available supplies. Every year, the Board of Directors determines an "April Quota" which sets the maximum amount of water to be available from project supplies for the current year. A quota of 100 percent means that 310,000 acre-feet of water can be used by the shareholders during that season, in which case one CBT unit holds a right to one acre-foot of delivered water. A 70 percent quota would yield 0.7 acre-foot per CBT unit. The annual quota is set according to hydrologic conditions (snowpack, runoff forecast, soil moisture,

[3] Main source for the remainder of the chapter: Northern Colorado Water Conservancy District.


Northern Colorado Water Conservancy District
COLORADO-BIG THOMPSON PROJECT
FACILITIES AND DISTRICT BOUNDARIES
West Slope Collection System
Grand Lake
GRAND LAKE
SHADOW MOUNTAIN RESERVOIR
WILLOW CREEK RESERVOIR
LAKE GRANBY
WINDY GAP RESERVOIR
Granby
WYOMING
NEBRASKA
COLORADO
Cheyenne
LARIMER
JACKSON
WELD
MORGAN
LOGAN
SEDGWICK
PHILLIPS
WASHINGTON
YUMA
BOULDER
GRAND
GILPIN
CLEAR CREEK
JEFFERSON
ADAMS
SUMMIT
PARK
Continental Divide
Halligan Reservoir
Seaman Reservoir
Chambers Lake
HORSETOOTH RESERVOIR
Fort Collins
Windsor Reservoir
Greeley
Loveland
Boyd Lake
Estes Park
LAKE ESTES
MARY'S LAKE
PINEWOOD RESERVOIR
FLATIRON RESERVOIR
CARTER LAKE
Longmont
Union Reservoir
Button Rock Reservoir
BOULDER RESERVOIR
Boulder
Superior
Broomfield
Barker Reservoir
Gross Reservoir
Standley Lake
Ralston Reservoir
Denver
Cherry Creek Reservoir
Chatfield Reservoir
Ft. Lupton
Hudson
Horse Creek Reservoir
Barr Lake
New Denver International Airport
Lower Latham Reservoir
Milton Reservoir
Riverside Reservoir
Empire Reservoir
Jackson Lake
Bijou Reservoir
Fort Morgan
Prewitt Reservoir
Sterling
North Sterling Reservoir
Jumbo Reservoir
Julesburg
South Platte River
Kremmling
Williams Fork Reservoir
GREEN MOUNTAIN RESERVOIR
Dillon
Dillon Reservoir
East Slope Distribution System
NCWCD Headquarters
Legend
District Boundaries
Power Plant
Pump Plant
Pipeline
Tunnel
Canal
Dam
US Index Map
Colorado Index Map
N
J.A.D. 5/92
Scale of Miles (Approximate)

reservoir storage) and planned water demand for the current and potential future dry years. According to the primary purpose of the project, water is saved during wet years and made available for delivery during dry years. However, the April quota may be increased at any time by the board when required by the hydrologic conditions of the year. Figure 4-3 displays the evolution of annual quotas and deliveries since 1957. The long-run average yield of CBT units has been 0.73 acre-foot per unit since 1957. Annual deliveries have averaged 65 percent of the 310,000 maximum acre-feet on the same period. The yield corresponds to the quota, or the annual quantity of water available for use, whereas deliveries represent the quantities actually used. An interesting point is that water users take relatively less of their allotment during low-quota years than they do during high-quota years: annual deliveries average 81 percent of the quota when the latter is less than 75 percent (wet years), and 90 percent when the quota is 75 percent or above (dry years).

Rights to CBT water are highly transferable within the district service area. Not only can allottees seasonally rent and transfer water from one location of use or class of service to another, but they can also sell, purchase or exchange permanent allotment contracts. Return flows cannot be appropriated and the complete rights to primary flow (i.e., the full share allotment) can be transferred. Plus, the complex network of reservoirs (over 60) and ditches makes water physically easy to transfer anywhere within the district service area. The only constraint on permanent transfers (working as a hedge against excessive speculation) is that water must be put to beneficial use for the transfer to be approved by the board.

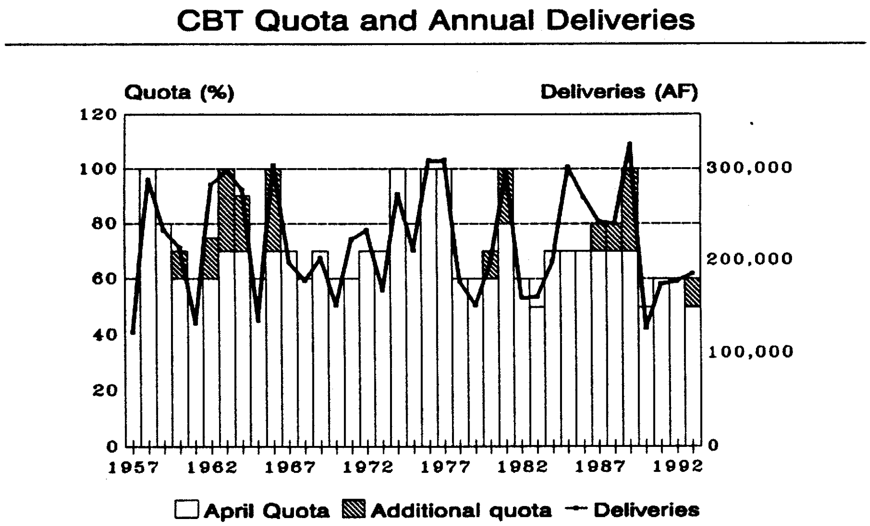


Figure 4-3

Annual fees are collected on each acre-foot unit in order to cover the fixed and operating costs of the project (assessment costs). The history of CBT assessments is summarized in Table 4-1.

A carry-over policy was introduced in 1986. Prior to this time, an allottee's unused water would be stored to increase the project water available in subsequent years for all contract allottees. With the carry-over policy, water unused by an allottee in a particular water year can be carried over for use from April 1 to July 15 of the following year. This policy has introduced more flexibility in the way water can be used.

During high runoff years, when CBT storage is fully utilized, non-charge (unappropriated surplus) water is released into the district's service area. Allocation of non-charge water is managed by river commissioners, and does not necessarily

Table 4-1: Summary of District Water Assessment Charges (nominal dollars per unit)

Year	Irrigation	Municipal & Domestic	Industrial	Multi-purpose
1939-58	1.50	1.50		1.50
1959-64	1.50	3.00		2.50
1964-66	1.50	5.00		2.50
1966-74	2.00	5.00	4.50	3.50
1974-81	2.00	5.00	8.00	5.00
1981-83	2.50	6.25	10.00	6.25
1983-84	3.50	8.25	13.00	8.25
1984-86	4.50	10.50	16.25	10.50
1986-91	4.50	10.50	16.25	12.00
1991-93	5.40	12.60	19.50	19.50
1993-94	5.95	13.85	21.45	21.45

Source: Northern Colorado Water Conservancy District

correspond to the contract allotments. Non-charge plus carry-over water deliveries have averaged 71,570 acre-feet per year since 1983, except for 1990 where no delivery of non-charge and carry-over water occurred (Table 4-2).

4.4.2 CBT water ownership and utilization patterns

The majority of CBT shares have traditionally been owned by the agricultural sector, especially in the early days of CBT service. Since then, municipalities and industries have been bidding water away from irrigation to cover their immediate and future needs. Figure 4-4 describes the evolution in CBT share ownership and water deliveries in agricultural and non-agricultural sectors. From the graph, it can be seen that agriculture uses more water than it owns, suggesting that municipalities rent their unneeded water to irrigators. Given that the CBT project is intended to provide

Table 4-2: Summary of Non-charge and Carry-over Water Deliveries

Year	Non-Charge	Carry-over	Total
1962	103,977	-	103,977
1971	60,326	-	60,326
1983	62,046	-	62,046
1984	72,729	-	72,729
1985	120,860	-	120,860
1986	129,595	514	130,109
1987	26,312	41,240	67,552
1988	-	38,064	38,064
1989	-	49,082	49,082
1990	-	-	-
1991	-	39,294	39,294
1992	-	58,970	58,970
1993	-	76,966	76,966

Source: Northern Colorado Water Conservancy District

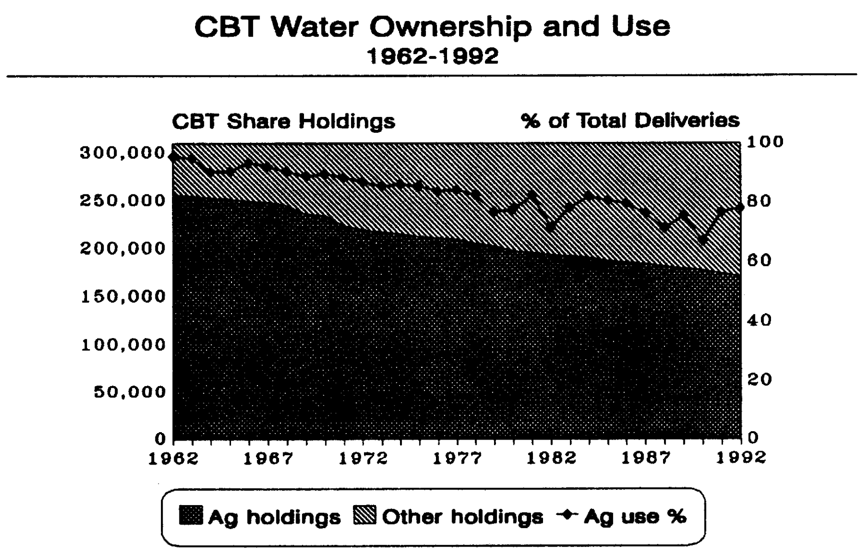


Figure 4-4

supplemental water only, annual deliveries of CBT water are highly variable, depending on hydrologic conditions (Figure 4-5). Nevertheless, several municipalities

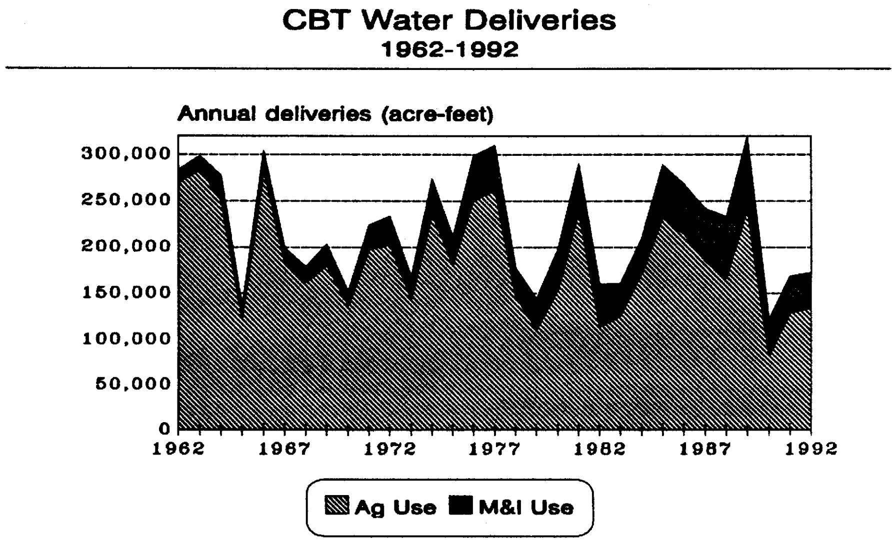


Figure 4-5

rely on CBT deliveries as a primary source of water.

Along with the shift in ownership and use of CBT water, irrigated acreage within the NCWCD has been shrinking over the past thirty years. From 720,000 acres in 1960, the acreage receiving irrigation water has come down to 622,272 acres in 1993 (NCWCD). Irrigation use patterns within the NCWCD are summarized in Figure 4-6.

The main crops are corn (grain and silage), hay, other cereals, pinto beans and sugar beets. Although vegetable crops represent only a small portion of the total irrigated acreage, they carry a higher aggregate crop value than any other crop category. The acreage and associated values by crop group for 1993 are given in Table 4-4.

Irrigated Crop Distribution Within the NCWCD
1993

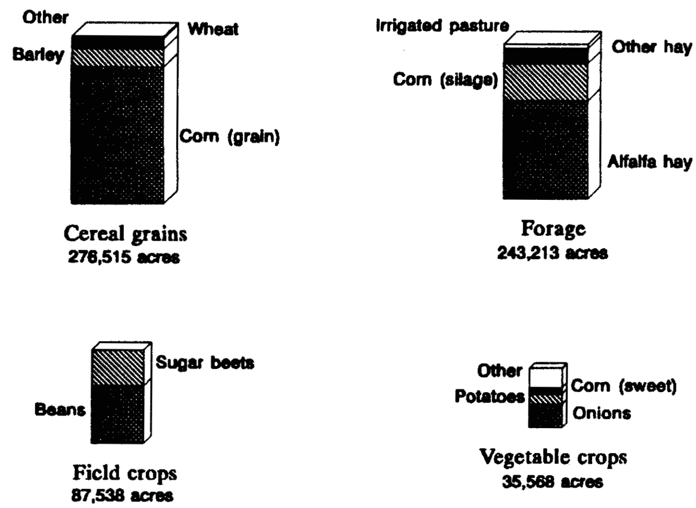


Figure 4-6

Table 4-4: 1993 Acreage and Value of Crops, by Group, Within the NCWCD

Crop	Cereal Grains	Forage	Field crops	Vegetable crops
Harvested acreage	276,515	243,213	87,538	35,538
Total Value (1,000 $)	81,133	88,024	60,406	113,658

Source: Northern Colorado Water Conservancy District

4.5 The Windy Gap Project

The CBT project was supplemented in the 1980's by the development of the Windy Gap project, whose purpose was to firm up municipal supplies of water. Given the annual variability of CBT deliveries, the "Municipal Subdistrict" of the NCWCD was formed in 1970 to develop supplemental water supplies that would stabilize water availability. The Settlement Agreement was signed on April 30, 1980, which represents the key date for the Windy Gap project launching. Development started in 1981 and the first deliveries were made in 1985. According to the Carriage Contract of October 1973, Windy Gap water is delivered through CBT structures. However, Windy Gap water is allocated separately from CBT water rights. The ratification of the settlement agreement, which was the real starting point of the project, is expected to have played a role in CBT price evolution and will be incorporated in the analysis of CBT unit prices. Table 4-3 summarizes the distribution of Windy Gap units among its allottees and Figure 4-7 shows the evolution of Windy Gap deliveries since 1985.

Table 4-3: Windy Gap Project Allotments

Allottees	Units	Acre-Feet	Percentage
Platte River Power Authority	160	16,000	33.33%
Longmont	80	8,000	16.67%
Greeley	67	6,700	13.96%
Broomfield	56	5,600	11.68%
Loveland	40	4,000	8.33%
Boulder	37	3,700	7.70%
Superior Metropolitan District No. 1	35	3,500	7.28%
Estes Park	3	300	0.63%
Central Weld County Water District	1	100	0.21%
Left Hand Water District	1	100	0.21%
TOTAL	**480**	**48,000**	**100%**

Source: Northern Colorado Water Conservancy District

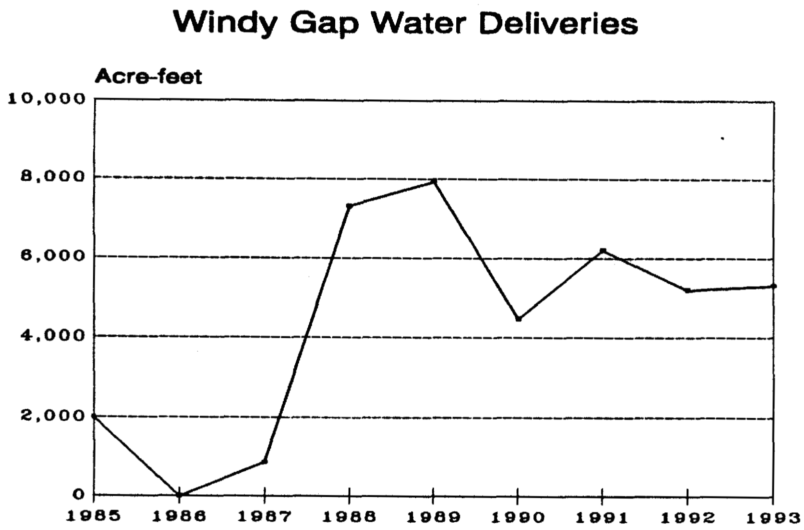


Figure 4-7

4.6 Conclusion

The case study area just presented was selected in part because of its long history of permanent water right transfers. The economic characteristics of the area, along with the transfer-facilitating character of Colorado water law gave rise to a well-established water market, which constitutes an excellent setting for this analysis. The effect of the addition of the Windy Gap project on CBT water right prices is investigated and integrated into the analysis.

CHAPTER FIVE: THE DATA

5.0 Introduction

This chapter presents information on water right prices and on economic and market factors that are used in this analysis. This information was collected and used based on the identification of potential price determinants performed in Chapter Three. Details are given on data sources, coding or other transformation schemes, missing data and limitations of available series. A descriptive analysis of the CBT market is performed in the following chapter.

5.1 CBT data

Given the nature of water right markets, information on physical amounts of water transferred are usually available, but the corresponding price information is undisclosed. Water-related economic research is often limited by the quantity and quality of price data which are available. The present study is no exception: in order to have a complete picture of the CBT market, it was necessary to gather information on prices and transactions separately.

5.1.1 CBT price series

Two sets of price series for CBT water rights are used in this analysis. The first set is a series of annual average price of permanently sold CBT units from 1961 through 1989[4]. The second more detailed set consists of published prices for individual transactions, only available from December 1986 through the present.

Information on average annual prices for CBT shares was collected from several sources (city water departments, brokers, NCWCD) and compiled to produce a price time series from 1961 to 1989. The variety of sources suggests that these average annual prices accurately reflect market price levels during this period. Figure 5-1 describes the evolution of CBT prices, both in nominal and 1992 $ value (deflated using the GNP implicit price deflator).

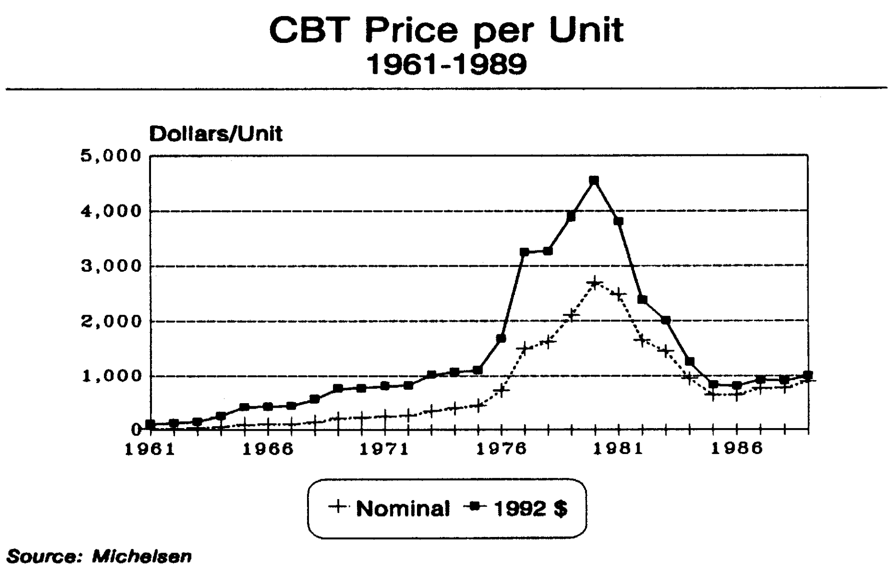


Figure 5-1

Unfortunately, this price series does not provide any insight on the price dispersion for each year nor on the number of annual transactions actually taking

[4] Compiled by Dr. Ari M. Michelsen, Associate Director, Wyoming Water Resources Center, University of Wyoming, Laramie, WY.

place. For this reason, it was supplemented by price and transaction information published in the Water Intelligence Monthly from 1986 through 1993, and by monthly transfer approvals recorded in the NCWCD Board meeting minutes.

The monthly newsletter 'Water Intelligence Monthly' (formerly 'Water Market Update' started in December 1986) publishes the water right transactions on which information could be collected and printed. Published information on CBT transfers make a valuable contribution to our CBT market description. Table 5-1 summarizes this information and Figure 5-2 displays the evolution and dispersion of CBT water right prices.

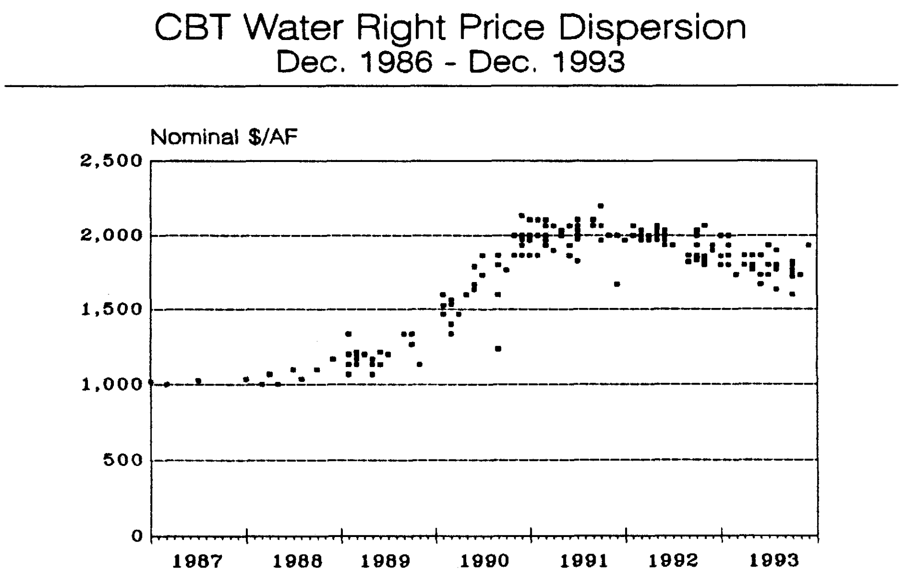


Figure 5-2

Based on the increase in the number of transactions reported, information is more readily available from 1989 on than it was during the two first years. Market

Table 5-1: Published Transactions of CBT Units

Year	Transactions		CBT units	Price/Unit	Standard	Price/AF	Price/AF
	Type	Number	transferred	Nominal	Deviation	Nominal	1992 $
1986	Sale	1	1780	762.50	0	1,016.67	1,270.57
1987	Sale	3	783	765.00	11	1,020.00	1,235.22
	Exch	5	116				
1988	Sale	11	5139	781.82	41	1,042.42	1,214.99
	Exch	1	80				
1989	Sale	23	1528	896.96	59	1,195.94	1,336.06
	Exch	1	1020				
1990	Sale	43	4173	1,299.35	158	1,732.47	1,858.30
	Exch	1	70				
1991	Sale	48	3302	1,502.29	66	2,003.06	2,060.92
	Exch	1	100				
1992	Sale	46	3118	1,459.89	59	1,946.52	1,946.52
	Exch	5	131				
1993	Sale	46	1715	1,339.46	64	1,785.94	1,744.17
	Exch	35	576				
Total		270	23631				

Note: Prices are average (mean) annual prices.
Source: Compiled from individual issues of *Water Market Update* and *Water Intelligence Monthly.*

participants may well have been reluctant at the beginning to reveal what was considered to be proprietary information. The critical aspect of that data is the limited price dispersion at any point in time. Except for a relatively small number of outliers (Figure 5-2), CBT water right prices at a given point in time are clustered with small variation. This strongly suggests that price information is efficiently carried by the market (brokers probably play a crucial role in this aspect), and that a time series analysis is more insightful than a cross-sectional analysis. A portion of water right transactions take place in the form of exchanges: typically, individuals and developers provide raw water to a community or water district in exchange for water service.

If we assume that the level of price dispersion has remained fairly constant since 1961, the use of average annual prices appears both legitimate and accurate. Subsequently, the two price series have been combined to produce a complete series from 1961 to 1993 that will serve as a basis for our analysis (Figure 5-3).

Prices of Colorado-Big Thompson Water Shares
1961-1993

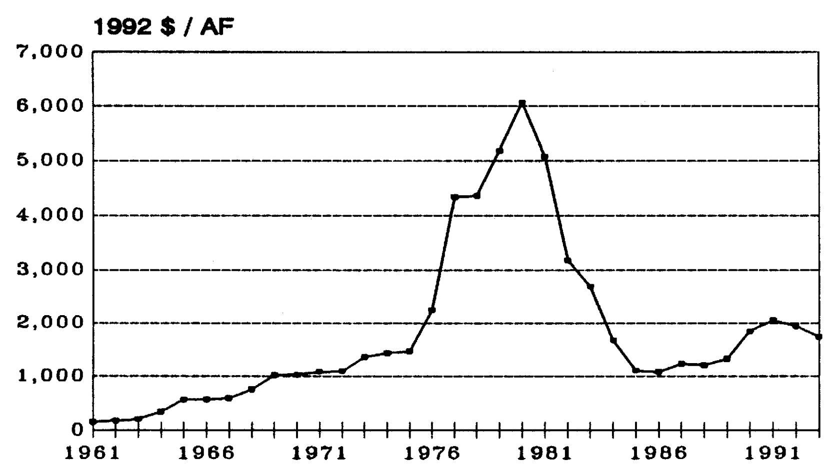


Figure 5-3

In order to facilitate the comparison of CBT prices with prices of other water rights, an estimated price per acre-foot was generated using a conversion factor of 0.75 acre-foot per unit. This corresponds to the conversion factor used by major cities and water districts in the NCWCD, but is slightly (0.03 AF) over the calculated long-run yield of CBT units (see Section 4.4.1).

However, to better understand the conditions that contribute to CBT price variation over time, more information was needed concerning the quantitative (market activity) and qualitative (seller and buyer typology) aspects of CBT water transfers. The following section provides additional information.

5.1.2 CBT transactions

Based on the identification of potential water right price determinants performed in Chapter Three, information on market activity and structure was necessary to carry out the descriptive and econometric analysis. This information was partially found in the minutes of the NCWCD Board of Directors monthly meetings.

As described earlier, all transactions within the NCWCD have to be approved by the Board of Directors. Transfer applications are reviewed every month during Board meetings, and all approvals are recorded in the minutes of these meetings. Transfer price is undisclosed to the Board, but every single transaction is reported, with the names of the applicants, the type of contract (which refers to the type of use), the quantity of water involved and the geographical description of the land on which water is to be applied (irrigation only). An example of reported approvals is provided in Appendix 1. The Board has to review all contract modifications, from a change in an entity's name, to a transaction involving land only (the remaining water having to be administered under a new contract), to transactions involving water only or both land and water. Also, personnel changes made it impossible to accurately interpret details about individual transfers. Although monthly minutes exist back to 1961 and earlier, time constraints together with the existence of a different reporting format prior to 1970 meant that it was only feasible to investigate these transfers in detail from 1970 through 1993.

The data were categorized and numerically coded for quantitative analysis by type of seller and buyer, type of contract, and type of water use prior to and after the transfer. All transactions involving only a change in location of use for the same entity were discarded. A coding scheme was developed for applicant types as follows:

1- Individuals, farms, ranches, farm and cattle companies;

2- Irrigation companies;

3- Municipalities, water districts;

4- Industries;

5- Developers;

6- Banks, insurance companies;

7- Investment companies;

8- Churches;

9- Other.

Contracts were all either irrigation contracts (associated with a piece of land) or corporate (irrigation companies, municipalities or industries). The type of use was derived from the first two codings. For example, a manufacturing company might hold water under an irrigation contract because it owns farming land, or a corporate contract may be used for irrigation by an irrigation company. Finally, knowing the former and the new use for each contract transferred provided a means to classify the transactions, as described below:

1- Agriculture to Agriculture;

2- Agriculture to Domestic;

3- Agriculture to Industry;

4- Domestic to Agriculture;

5- Domestic to Domestic;

6- Domestic to Industry;

7- Industry to Agriculture;

8- Industry to Domestic;

9- Industry to Industry.

Classification of water right user categories is based on the names of the applicants and type of contracts (stating use) that were reported in the minutes. In some cases this required assistance from personnel at the NCWCD (the contribution of Marilyn Conley on data interpretation was invaluable) and judgement calls.

Limitations of the raw information may have led to a slight overestimation of the total actual transfers of CBT water from 1970 to 1993. The reason for this is that simple name changes may have been erroneously interpreted as transactions. However, the degree of error is presumed to be small and consistent throughout the whole period, leaving annual variations unaffected.

A second type of potential interpretation error concerns the applicants' typology. Types 1 (Individuals, farms...), 5 (Developers) and 7 (Investment companies) were difficult to distinguish from each other because the contracts are identical and the names may not be explicit. A related limitation is that only the immediate new use of water is reported, and not the long-term purpose of use. The consequence of these limitations is that the transactions involving developers may have been underestimated, and the descriptive analysis should be interpreted cautiously on this aspect. In general, all applicant types were clearly identifiable and the general classification (combining types 1, 5,and 7 together) is believed to be accurate. This information on CBT shares transactions is an important complement to the price series data and allows a better understanding of the market reactions over the reported period. An interpretation of this data is given in the next chapter.

5.2 Water value in irrigation

The price at which irrigators are willing to sell or to buy water is hypothesized to be related to the net revenue left to the farmer by irrigated crops. Following Gardner and Miller (1983), we retained corn as the most representative crop for the area, given its acreage dominance (approximately 50 percent of total irrigated acreage) and intermediary value between alfalfa and field crops. Unfortunately, no data are available on crop-specific production costs prior to 1975, when they were first reported by the U.S. Department of Agriculture for the major crops. A publication from the Economic Research Service of the U.S.D.A. titled *Costs of*

Production - Major Field Crops; 1990 provided us with the information needed to compute annual net revenue per acre of corn from 1975 to 1990. Because of limited data availability, information on crop net revenues is not used in the econometric model, but it is used in the descriptive analysis, providing some interesting insight on the evolution of willingness-to-pay for water in agriculture. The data are summarized in Table 5-2.

Table 5-2: Per Acre Returns from Irrigated Corn

Year	Nominal Dollars Per acre of corn				
	Corn Gross value	Variable cash expenses	Fixed cash expenses	Unpaid labor	Net Returns
1975	190.17	68.82	47	6.91	67.44
1976	170.54	69.11	46.82	9.78	44.83
1977	185.46	72.83	48.5	11.89	52.24
1978	226.96	77.16	43.68	8.41	97.71
1979	268.98	94.96	48.93	10.17	114.92
1980	248.63	111.93	58.46	11.54	66.7
1981	256.86	136.14	78.57	13.25	28.9
1982	232.55	125.05	77.56	13	16.94
1983	244.74	122.25	84.32	12.86	25.31
1984	263.79	124.93	82.62	13.77	42.47
1985	257.16	135.75	60.18	14.34	46.89
1986	170.09	113.45	34.22	19.15	3.27
1987	183.27	111.38	30.22	17.7	23.97
1988	274.62	116.62	29.69	19.05	109.26
1989	235.64	125.64	29.67	20.36	59.97
1990	245.24	128.74	32.17	20.65	63.68

Source: *Costs of Production - Major Field Crops, 1990,* Economic Indicators of the Farm Sector, Economic Research Service, U.S. Dept. of Agriculture.

Given the lack of data on crop net revenue for the entire period, the gross revenue per acre of corn, i.e., yield times price per bushel, is used as an estimate of agricultural returns to water. A series on corn gross revenue was developed using crop yield and price information from *Agricultural Statistics* (U.S. Department of Agriculture) for the 1960-1992 period and for the State of Colorado. These data are provided in Tables 5-4a and 5-4b.

5.3 CBT water rights and other natural resources

If speculation exists in water right markets and water rights are being used as an investment good, there may be some relation between prices of water rights and the prices of other natural resource commodities that are subject to speculation. Prices of crude oil, gold, silver and farmland were collected for the 1960-1992 period to examine potential relationships with water right prices. The data and data sources are given in Tables 5-3a and 5-3b.

5.4 Economic and market factors

Economic and market factors were hypothesized to be major determinants of water right markets and prices. The corresponding information series are described below along with the sources, and are all reported in Tables 5-4a through 5-4c at the end of this chapter.

Population and per capita income were collected from the *Regional Economic Information System*, Table CA05 (Bureau of Economic Analyses, U.S. Department of

Table 5-3a: Nominal Prices of CBT Units and Selected Natural Resources

Year	CBT $/unit	CBT $/acre-foot	Crude Oil $/bbl (1)	Farmland $/acre (2)	Silver $/troy (3)	Gold $/troy (3)
1960	-	-	2.88	54	-	-
1961	25	33	2.89	55	0.924	-
1962	30	40	2.9	61	1.085	-
1963	35	46	2.89	65	1.279	-
1964	60	80	2.88	68	1.293	-
1965	100	133	2.86	71	1.293	-
1966	105	140	2.88	78	1.293	-
1967	112	149	2.92	83	1.55	-
1968	150	200	2.94	87	2.145	-
1969	212	282	3.09	92	1.791	-
1970	225	300	3.18	95	1.771	-
1971	250	333	3.39	103	1.546	-
1972	265	353	3.39	116	1.685	-
1973	350	466	3.89	137	2.558	-
1974	400	533	6.87	175	4.708	-
1975	450	600	7.67	188	4.419	-
1976	730	973	8.19	219	4.353	-
1977	1502	2002	8.57	256	4.623	148
1978	1629	2172	9	273	5.401	193.4
1979	2106	2808	12.64	322	11.094	307.6
1980	2696	3595	21.59	387	20.632	612.5
1981	2481	3308	31.77	434	10.518	459.6
1982	1652	2203	28.52	451	7.947	376
1983	1454	1939	26.19	454	11.441	423.8
1984	950	1267	25.88	469	8.141	360.3
1985	650	867	24.09	437	6.142	317.3
1986	650	867	12.51	360	5.47	367.9
1987	765	1020	15.4	368	7.009	446.5
1988	782	1043	12.58	369	6.535	436.9
1989	897	1196	15.86	367	5.499	381.3
1990	1299	1732	20.03	358	4.79	384.1
1991	1502	2003	16.54	410	4.04	362.04
1992	1460	1947	15.99	367	3.938	344.5
1993	1345	1793	15.06	383	4.205	354.85

Sources: (1) "Other U.S." Domestic First Purchase Price (including Alaska North Slope), Table 65, *Annual Energy Review*, Energy Information Administration, U.S. Dept. of Energy.
(2) Average per Acre Value of Farm Real Estate, by State, Table 1, *Situation and Outlook Summary* (Agricultural Resources: Agricultural Land Values), Economic Research Service, U.S. Dept. of Agriculture.
(3) Gold and Silver Annual Average Prices at New York, *Survey of Current Business*, July Summary, Bureau of Economic Analyses, U.S. Dept. of Commerce.

Table 5-3b: GNP Implicit Price Deflator and Constant 1992 Dollar Prices of CBT Units and Selected Natural Resources

Year	GNP Implicit Price Deflator (1987=100)	GNP Multiplier (1992=1)	CBT 1992 $ per AF	Crude Oil 1992 $ per bbl	Farm estate 1992 $ per acre	Silver 1992 $ per troy	Gold 1992 $ per troy
1960	26.0	4.658	-	13.41	251.52	-	-
1961	26.3	4.605	153.49	13.31	253.25	4.25	-
1962	26.8	4.519	180.75	13.10	275.64	4.90	-
1963	27.2	4.452	207.77	12.87	289.39	5.69	-
1964	27.7	4.372	349.75	12.59	297.29	5.65	-
1965	28.4	4.264	568.54	12.20	302.75	5.51	-
1966	29.4	4.119	576.67	11.86	321.29	5.33	-
1967	30.3	3.997	596.84	11.67	331.73	6.19	-
1968	31.8	3.808	761.64	11.20	331.31	8.17	-
1969	33.4	3.626	1024.88	11.20	333.57	6.49	-
1970	35.2	3.440	1032.10	10.94	326.83	6.09	-
1971	37.1	3.264	1088.05	11.07	336.21	5.05	-
1972	38.9	3.113	1099.97	10.55	361.12	5.25	-
1973	41.3	2.932	1368.36	11.41	401.71	7.50	-
1974	44.9	2.697	1438.46	18.53	471.99	12.70	-
1975	49.2	2.461	1476.83	18.88	462.74	10.88	-
1976	52.3	2.315	2253.74	18.96	507.09	10.08	-
1977	55.9	2.166	4338.51	18.57	554.59	10.02	320.62
1978	60.3	2.008	4362.01	18.07	548.26	10.85	388.40
1979	65.6	1.846	5183.67	23.33	594.42	20.48	567.84
1980	71.7	1.689	6071.33	36.47	653.64	34.85	1034.50
1981	78.9	1.535	5077.30	48.76	666.13	16.14	705.42
1982	83.8	1.445	3183.09	41.21	651.74	11.48	543.36
1983	87.2	1.389	2692.35	36.37	630.50	15.89	588.56
1984	91.1	1.329	1683.79	34.40	623.45	10.82	478.95
1985	94.4	1.283	1111.79	30.90	560.60	7.88	407.04
1986	96.9	1.250	1083.11	15.63	449.91	6.84	459.78
1987	100.0	1.211	1235.22	18.65	445.65	8.49	540.71
1988	103.9	1.166	1215.27	14.66	430.09	7.62	509.23
1989	108.4	1.117	1336.12	17.72	410.00	6.14	425.97
1990	112.9	1.073	1857.80	21.48	384.00	5.14	412.00
1991	117.7	1.029	2060.52	17.02	421.84	4.16	372.50
1992	121.1	1.000	1946.67	15.99	367.00	3.94	344.50
1993	124.0	0.977	1751.39	14.71	374.04	4.11	346.55

Source for GNP Implicit Price Deflator: ***Survey of Current Business*** and ***Business Statistics***, Bureau of Economic Analyses, U.S. Dept. of Commerce.

Commerce) for Boulder, Larimer and Weld counties, the most urbanized counties encompassing most of the NCWCD service area. However, information on per capita income was not available at the county level prior to 1969. Therefore, the missing data were estimated using a regression on the state figures for per capita income (which existed prior to 1969). Regressing the average annual per capita income (PCI) for Boulder, Larimer and Weld counties on Colorado PCI for the period 1969-1983 produced the following model:

$$PCI\ \frac{(B+L+W)}{3} = 4.1698 + 0.9098\ PCI\ Colorado$$
$$with\ \ R^2 = 0.9978;\ \ R^2_{Adj} = 0.9977$$

This model was then used to generate the missing data from 1960 to 1968. The accuracy of the backcast was checked by comparing the generated 1960 average PCI with 1960 census values of PCI, by county, published in *County and City Data Book* (U.S. Department of Commerce, Bureau of the Census). The same procedure was used to generate the 1992 average PCI value, unpublished at the time of analysis, for the three counties of interest. A second regression model for the 1977-1991 period produced the following results:

$$PCI\frac{(B+L+W)}{3} = -691.1774 + 0.9796\ PCI\ Colorado$$
$$with\ \ R^2 = 0.9933;\ \ R^2_{Adj} = 0.9928$$

The excellent fit obtained with both models (R^2) suggests that the produced values for

PCI are very close to the real values and helps to legitimize the procedure.

The number of housing construction starts for Boulder, Larimer and Weld counties were collected from the *Housing Units Authorized by Building Permits* (Current Construction Reports, U.S. Department of Commerce, Economic and Statistics Administration, Bureau of the Census) for the 1960-1992 period.

Farm debt-to-asset ratio information was obtained from the *Farm Sector Balance Sheet, Including Operator Households, 1960-89* (Table 22, Economic Research Service, U.S. Department of Agriculture) and from *Economic Indicators of the Farm Sector, State Financial Summary* (Economic Research Service, U.S. Department of Agriculture) for the state of Colorado for the whole period 1960-1992. Plus, for descriptive purposes, data on farms total liabilities in Colorado were also gathered from the same sources (1991 and 1992 figures were still unpublished at the time of analysis).

As discussed earlier, the number of farm foreclosures (usually done by banks) was hypothesized to affect water right prices through its influence on the market supply of water rights. However, a detailed analysis of the CBT market (described in the next chapter) indicates that the banking sector is an insignificant market participant. Consequently, it was decided not to use this variable.

All prices and values were converted to constant 1992 dollars using the Gross National Product implicit price deflator as published by the U.S. Department of Commerce Bureau of Economic Analyses in the July Annual Summary issue of the *Survey of Current Business*. This deflator was also used to calculate annual inflation rates from 1960 to 1992.

The prime rate charged by commercial banks is used as a measure of investment interest rates (opportunity cost of money) (*Economic Report to the President 1993*, Table B-72: "Bond Yields and Interest Rates, 1929-93," U.S. Government Printing Office). Inflation rates calculated from the price index were then used to compute real prime rates, which should reflect the real cost of money.

Information on CBT market structure was either obtained directly from the NCWCD, or produced after interpretation of the CBT transaction data. The ratio of agricultural-to-other holders came from the District, which reports annual CBT share ownership among four classes: irrigation, domestic, multi-purpose and industrial. This information was also used to estimate the relative acquisitions made by the municipal and industrial sectors every year. However, it was necessary to know the total number of CBT units transferred every year, i.e., not only the units transferred from one type of use to another, but also the units transferred within the same type of use (not reported here). Since the transfers from irrigators to irrigators are the only significant intra-category transfers, they were estimated from the 1970-1993 transaction data collected at the NCWCD. The results were used for the 1970-1993 period, and, given their limited variation, the average was used prior to 1970. In this manner, we were able to develop a series representing the relative annual acquisitions made by the municipal sector.

5.5 Hydrology

Information on annual rainfall within the NCWCD was obtained from the District for the period under investigation.

5.6 Data Tables

The numerical data used in the analysis are summarized in Tables 5-4a through 5-4c.

Table 5-4a: CBT Market Information

Year	GNP Implicit Deflator (1987=100) (1)	GNP Implicit Multiplier (1992=1)	CBT Price Per Unit (Nominal) (2)	CBT Price Per AF (Nominal)	CBT Price Per AF (1992 $)	Munic buyers (%) (3)	CBT units held in Agriculture (Units) (3)
1961	26.3	4.605	25	33	153.49	-	257253
1962	26.8	4.519	30	40	180.75	-	255690
1963	27.2	4.452	35	47	207.77	-	254127
1964	27.7	4.372	60	80	349.75	-	252563
1965	28.4	4.264	100	133	568.54	56.32	251000
1966	29.4	4.119	105	140	576.67	64.43	248804
1967	30.3	3.997	112	150	596.84	42.86	247895
1968	31.8	3.808	150	200	761.64	74.11	244426
1969	33.4	3.626	212	283	1024.88	42.09	235820
1970	35.2	3.440	225	300	1032.10	58.89	234023
1971	37.1	3.264	250	333	1088.05	28.57	223420
1972	38.9	3.113	265	353	1099.97	56.22	219381
1973	41.3	2.932	350	467	1368.36	59.65	216685
1974	44.9	2.697	400	533	1438.46	59.82	214507
1975	49.2	2.461	450	600	1476.83	56.23	212059
1976	52.3	2.315	730	973	2253.74	22.71	210722
1977	55.9	2.166	1502	2003	4338.51	45.71	209510
1978	60.3	2.008	1629	2172	4362.01	65.61	204648
1979	65.6	1.846	2106	2808	5183.67	54.65	201655
1980	71.7	1.689	2696	3595	6071.33	77.92	197377
1981	78.9	1.535	2481	3308	5077.30	47.56	194922
1982	83.8	1.445	1652	2203	3183.09	21.24	193394
1983	87.2	1.389	1454	1939	2692.35	36.25	191828
1984	91.1	1.329	950	1267	1683.79	48.82	189806
1985	94.4	1.283	650	867	1111.79	37.05	186886
1986	96.9	1.250	650	867	1083.11	56.34	185265
1987	100.0	1.211	765	1020	1235.22	185.62	183778
1988	103.9	1.166	782	1043	1215.27	67.18	181297
1989	108.4	1.117	897	1196	1336.12	65.32	179014
1990	112.9	1.073	1299	1732	1857.80	58.82	177234
1991	117.7	1.029	1502	2003	2060.52	73.50	173872
1992	121.1	1.000	1460	1947	1946.67	70.97	170909

Sources: (1) *Survey of Current Business*, Bureau of Economic Analyses, U.S. Dept. of Commerce.

(2) Composite series compiled from various sources (see text).

(3) Northern Colorado Water Conservancy District.

Table 5-4b: Economic Factors

Year	GNP Implicit Multiplier (1992=1)	Population (Boulder+ Larimer+ Weld Co.) (4)	Per Capita Income B+L+W/3 Nominal (4)	Per Capita Income B+L+W/3 1992 $	Building Permits B+L+W (5)	Inflation Rate (%)	Prime Rate (%) Nominal (6)	Prime Rate (%) Real
1961	4.605	212900	2194	10102.68	2683	1.15	4.5	3.35
1962	4.519	223900	2240	10123.86	2331	1.90	4.5	2.60
1963	4.452	233600	2302	10250.42	2774	1.49	4.5	3.01
1964	4.372	242100	2393	10463.15	3224	1.84	4.5	2.66
1965	4.264	250400	2548	10864.76	3255	2.53	4.54	2.01
1966	4.119	259600	2716	11188.5	2709	3.52	5.63	2.11
1967	3.997	270200	2870	11470.69	3704	3.06	5.61	2.55
1968	3.808	286100	3083	11740.35	4452	4.95	6.3	1.35
1969	3.626	299900	3396	12313.04	3755	5.03	7.96	2.93
1970	3.440	311086	3652	12565.27	4915	5.39	7.91	2.52
1971	3.264	328900	3899	12726.92	9191	5.40	5.72	0.32
1972	3.113	353900	4158	12945.35	9567	4.85	5.25	0.40
1973	2.932	374900	4606	13506.71	8088	6.17	8.03	1.86
1974	2.697	394300	5120	13810.07	4766	8.72	10.81	2.09
1975	2.461	398900	5728	14098.8	4048	9.58	7.86	-1.72
1976	2.315	403800	6370	14748.88	6288	6.30	6.84	0.54
1977	2.166	421100	6810	14752.97	8711	6.88	6.83	-0.05
1978	2.008	436100	7841	15747.02	8142	7.87	9.06	1.19
1979	1.846	452900	8832	16303.58	8149	8.79	12.67	3.88
1980	1.689	462247	9629	16262.64	3819	9.30	15.27	5.97
1981	1.535	472872	10762	16518.1	2673	10.04	18.87	8.83
1982	1.445	483392	11553	16694.84	3629	6.21	14.86	8.65
1983	1.389	494882	12071	16763.28	7300	4.06	10.79	6.73
1984	1.329	505832	13094	17406.41	7280	4.47	12.04	7.57
1985	1.283	510706	13724	17605.25	5596	3.62	9.93	6.31
1986	1.250	516708	14228	17781.75	4724	2.65	8.33	5.68
1987	1.211	523539	15004	18170.25	3747	3.20	8.21	5.01
1988	1.166	530618	15894	18525.54	2563	3.90	9.32	5.42
1989	1.117	537957	17151	19160.76	2450	4.33	10.87	6.54
1990	1.073	547788	18145	19462.88	2952	4.15	10.01	5.86
1991	1.029	556901	18626	19164.05	3423	4.25	8.46	4.21
1992	1.000	572002	19536	19536	5242	2.89	6.25	3.36

Sources: (4) *Regional Economic Information Service*, Table CA05, B.E.A., U.S. Dept. of Commerce.
(5) *Housing Units Authorized by Building Permits*, Bureau of the Census, U.S. Dept. of Commerce.
(6) *Economic Report to the President*, Table B-72: "Bond Yields and Interest Rates."

Table 5-4c: Agricultural Factors and Precipitation

Year	GNP Implicit Multiplier (1992=1)	Farms Debt-to-asset ratio (%) (7)	Farm Total Liabilities ($1,000,000) Nominal (7)	Farm Total Liabilities ($1,000,000) 1992 $	Corn Gross Revenue per Acre Nominal (8)	Corn Gross Revenue per Acre 1992 $	Precipitation (inches) (9)
1961	4.605	19.7	695	3488	63.44	292.09	19.70
1962	4.519	20.8	772	3873	64.80	292.81	13.67
1963	4.452	23.0	870	4070	78.65	350.17	12.97
1964	4.372	23.9	931	4537	87.54	382.73	8.02
1965	4.264	24.7	1064	4774	76.19	324.88	15.10
1966	4.119	25.1	1159	4904	105.60	434.97	9.83
1967	3.997	25.6	1227	4844	92.00	367.70	17.83
1968	3.808	25.1	1272	4822	99.12	377.47	11.81
1969	3.626	24.8	1330	4920	119.33	432.64	16.90
1970	3.440	24.6	1430	5043	126.72	435.96	12.53
1971	3.264	23.7	1545	5084	104.72	341.82	13.50
1972	3.113	21.2	1633	5260	173.88	541.31	11.23
1973	2.932	18.8	1794	5348	260.10	762.67	16.13
1974	2.697	20.5	1983	5479	297.95	803.60	12.09
1975	2.461	20.8	2226	6111	239.20	588.76	13.53
1976	2.315	21.6	2639	6447	229.50	531.40	12.52
1977	2.166	23.0	2976	6750	226.20	490.03	11.55
1978	2.008	21.9	3361	7043	231.00	463.92	14.18
1979	1.846	21.2	3815	6800	304.80	562.67	19.16
1980	1.689	20.0	4026	6743	359.90	607.86	14.90
1981	1.535	22.0	4393	6608	345.24	529.89	14.95
1982	1.445	22.0	4573	6480	358.62	518.24	15.67
1983	1.389	22.0	4666	6076	386.74	537.09	17.89
1984	1.329	23.0	4571	5136	356.44	473.82	16.38
1985	1.283	24.0	4004	4359	329.43	422.61	12.75
1986	1.250	21.0	3488	3935	224.00	279.94	14.15
1987	1.211	18.6	3249	3671	302.25	366.02	15.30
1988	1.166	17.8	3150	3471	406.40	473.68	14.01
1989	1.117	17.6	3107	3269	336.40	375.81	13.75
1990	1.073	15.5	3047	3056	365.80	392.37	15.27
1991	1.029	16.6	2970	-	371.79	382.53	13.11
1992	1.000	15.8	-	-	330.04	330.04	17.09

Sources: (7) *Farm Sector Balance Sheet, Including Operator Households, 1960-89*, Table 22, Economic Research Service, U.S. Dept. of Agriculture.

(8) *Agricultural Statistics*, Table 41 and 43, U.S. Dept. of Agriculture, Individual Issues 1960-1992.

(9) Northern Colorado Water Conservancy District.

CHAPTER SIX: CBT MARKET PRELIMINARY ANALYSIS

6.0 Introduction

This chapter provides a detailed description of the evolution of CBT prices, market activity and structure, and an examination of selected hypothesized determinants. Extensive use is made of graphs and tables in this descriptive analysis to better illustrate the relationships.

6.1 Evolution of CBT unit prices

Prices of CBT units have fluctuated widely over the past decades. It is interesting to track the price evolution trend since the CBT market was first established in the early 1960's. The average annual variation (in real terms) of CBT prices over five-year intervals is described in Figure 6-1. The annual percentage price variation has been extremely high during some time periods: +40.9% from 1961 to 1965, +36.3% from 1976 to 1980, and -28.1% from 1981 to 1985. The CBT price trend for the 1961 through 1993 period can therefore be summarized as follows: high positive growth before 1965, then moderate positive growth until 1975, high positive growth again from 1976 to 1980, turning point in 1980, high negative growth until 1985, second major turning point, moderate positive growth and flattening since then.

Following Blanchard and Watson (1982), Evans (1986) and Lo and MacKinlay (1988), we can define a run as a succession of positive (or negative) annual changes. Table 6-1 exhibits CBT price evolution in terms of runs (in this table each run is

Average Annual Variation in CBT Prices
Five Year Time Intervals

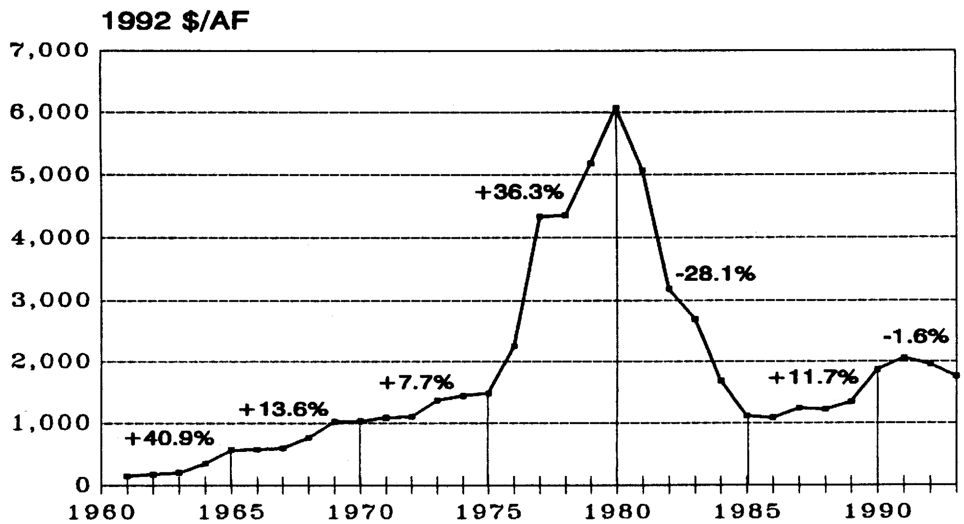


Figure 6-1

given a number for identification). It is interesting to note that the first runs are extremely long, positive at first, then negative. According to Evans (1986), this suggests that from 1961 to 1985, the market price was not well established. It is not until the second half of the 1980's that CBT prices appear to follow a random pattern, characteristic of a well established price. Plus, a succession of long positive and then negative runs is characteristic of the presence of a price bubble in the series. Given that the theoretical conditions for a speculative bubble to appear in water right markets are met (refer to Chapter Two), this simple empirical description suggests that the CBT market may have been subject to such a bubble in the first decades of its history.

Table 6-1: CBT Price History

Year	CBT Price 1992 $	Annual absolute change	Percentage change	Runs identification
1961	153	-	-	-
1962	181	27	17.8	1
1963	208	27	15.0	1
1964	350	142	68.3	1
1965	569	219	62.6	1
1966	577	8	1.4	1
1967	597	20	3.5	1
1968	762	165	27.6	1
1969	1025	263	34.6	1
1970	1032	7	0.7	1
1971	1088	56	5.4	1
1972	1100	12	1.1	1
1973	1368	268	24.4	1
1974	1438	70	5.1	1
1975	1477	38	2.7	1
1976	2254	777	52.6	1
1977	4339	2085	92.5	1
1978	4362	23	0.5	1
1979	5184	822	18.8	1
1980	6071	888	17.1	1
1981	5077	-994	-16.4	2
1982	3183	-1894	-37.3	2
1983	2692	-491	-15.4	2
1984	1684	-1009	-37.5	2
1985	1112	-572	-34.0	2
1986	1083	-29	-2.6	2
1987	1235	152	14.0	3
1988	1215	-20	-1.6	4
1989	1336	121	9.9	5
1990	1858	522	39.0	5
1991	2061	203	10.9	5
1992	1947	-114	-5.5	6
1993	1751	-196	-10.1	6

6.2 The CBT market activity and structure

Even though annual prices are available from 1961 through 1993, the descriptive analysis in this section is limited to the period 1970-1993, due to the lack of data on individual transactions prior to 1970. Transactions totalled 2,698 with 104,895 units transferred during this period. Given that the total number of CBT units is 310,000, as much as one third of CBT shares changed hands or type of use from 1970 to 1993. Thus, the level of market activity is extremely high and more information on market composition should be insightful.

First of all, let us compare the evolution in price to the trend in market

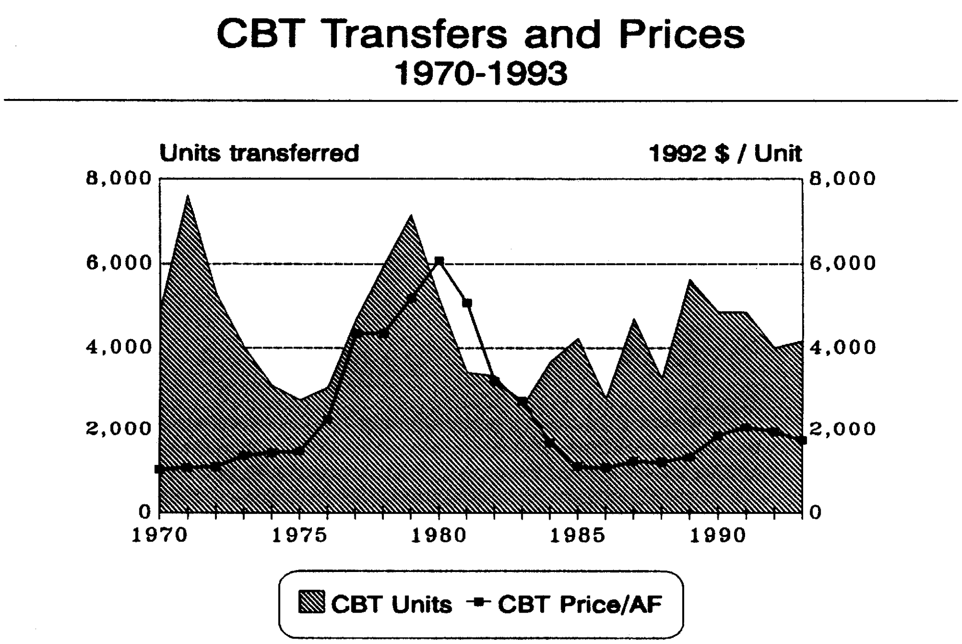


Figure 6-2

activity (Figure 6-2). The striking feature of this graph is the parallel between the two curves during the 1975-1985 period: the tremendous increase in price was accompanied by a similar increase in the number of units traded, suggesting a shift of the demand curve to the right. The composition of water right purchasers by use category is analyzed below. Even after 1985, the trends remain similar, although with lesser amplitude in the price curve. The first peak in market activity (in 1971) did not give rise to a significant increase in price. The reason for this is unclear. The fact that the CBT project was still fairly new at that time probably played a role.

The original and new purposes of use for traded CBT units by user category is given by Figures 6-3 and 6-4. (Tables containing this information are provided in Appendices 2 and 3.)

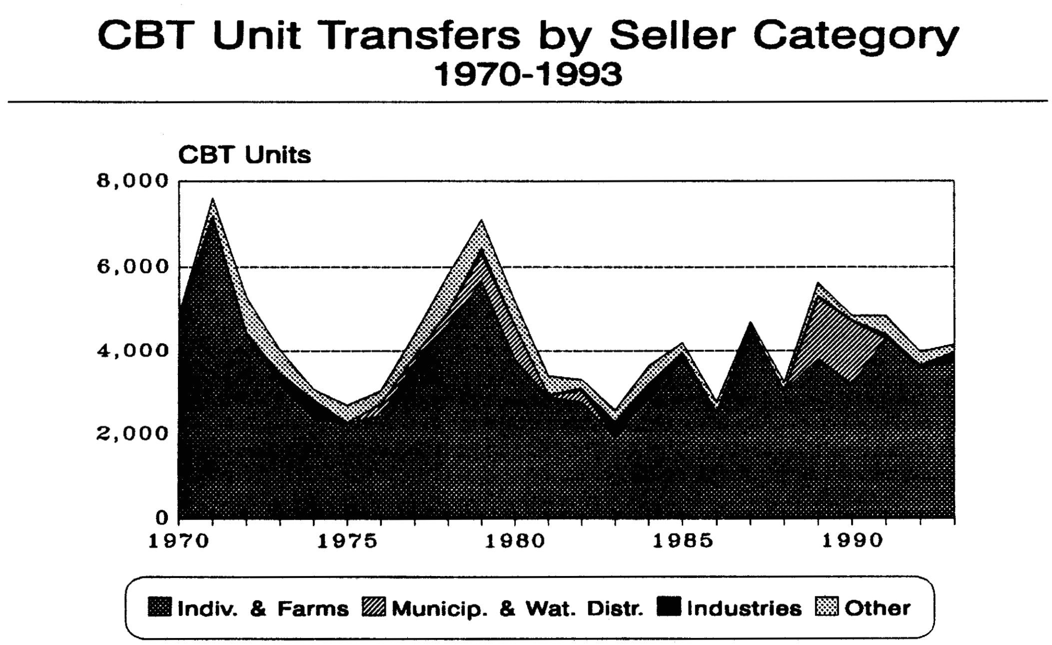


Figure 6-3

On the supply side, individual land-owners, farms and farm companies provide the great majority of CBT units being traded. A noticeable amount was supplied by

CBT Unit Transfers by Buyer Category
1970-1993

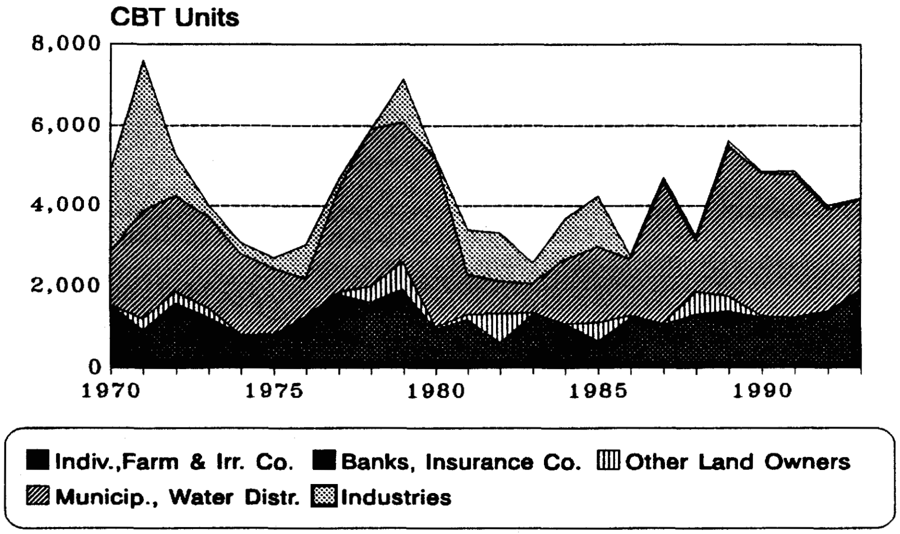


Figure 6-4

municipalities during two periods: in 1989 and 1990, and to a lesser extent around 1980. The user categories for CBT acquirers have a more balanced distribution. The agricultural sector has been quite constant in its acquisitions. An interesting detail is that the purchases of agricultural origin were highest during the periods of high prices, suggesting that irrigators did not only play the role of suppliers, but also contributed to the demand pressure right before 1980. In other words, high CBT prices did not stop agricultural purchases. The industrial sector purchased significant quantities of water in the 1970's and early 1980's. In particular, the 1971 peak in market activity appears to be due in large part to the industrial demand. At this time, the Public Service Company of Colorado (electricity production) and Eastman Kodak were purchasing significant amounts of water. The bulk of traded CBT units, however, were typically acquired by the municipal sector. As illustrated in Figure 6-4, the purchases by municipalities and municipal water districts was probably a significant factor contributing to the demand pressure especially during the period 1977-80 and 1987-92. The distribution of transactions by type for the 1970-1993 period is given in Table 6-2 and Figure 6-5.

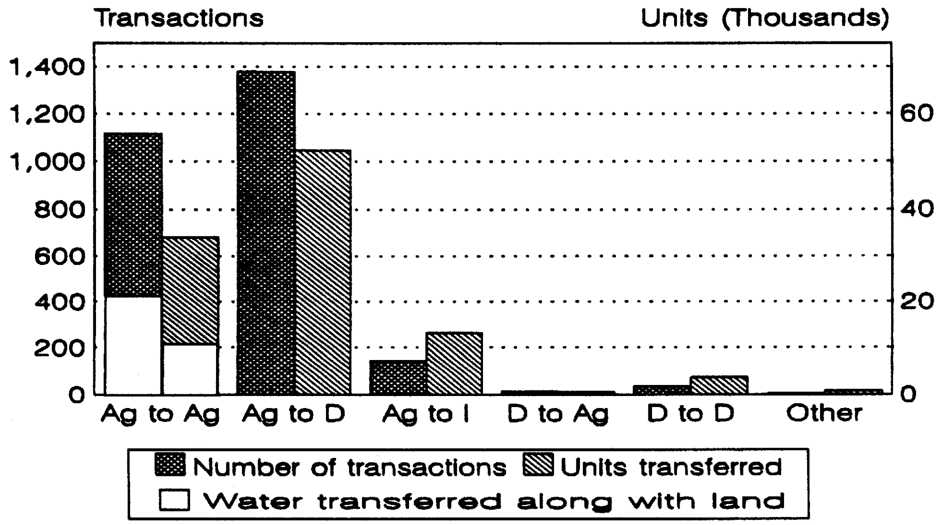
Table 6-2: Distribution of Transactions by Category of Seller and Purchaser (1970-93)

Transaction type	Number of transactions	Units transferred	Average units per transaction
Ag to Ag **including same land***	1116 446	34181 11133	30.6 25.0
Ag to Domestic	1379	52387	38.0
Ag to Industry	146	13170	90.2
Domestic to Ag	15	636	52.4
Domestic to Domestic	37	3715	100.4
Domestic to Industry	2	490	245.0
Industry to Ag	0	0	-
Industry to Domestic	1	11	11.0
Industry to Industry	2	305	152.5
Total	**2698**	**104895**	**38.9**

* CBT units traded along with a piece of land.

Water transferred along with a piece of land was reported separately from other transactions because in this case water may not have been the main reason for the transaction. Anyway, it is interesting to note that a large number of units were transferred within the agricultural sector itself. Although transfers of water from agriculture to other sectors are more noticeable and more widely discussed, a significant portion of traded irrigation water is put back to the same use. Again, only

Distribution of Transactions by Type
CBT Shares - 1970-1993



the immediate new use of water is reported for each transaction, and not the long-term purpose of use which sometimes reflects the real motivation for the investment. For example, a developer planning a future housing project may purchase water (and perhaps land) for this particular project, but will lease the water back for irrigation use until needed (also meeting the requirements for beneficial use). It is not until the water is transferred to a municipality that the true motivation of the first transaction appears in this data set. Nonetheless, this limitation should not be over-emphasized. Given the high level of market activity in the NCWCD, even farmers have been buying CBT shares and selling them a few years later, buying again and so on. This is a well-functioning market, which gives rise to a certain level of opportunistic behavior among market participants. Therefore, the most accurate picture available is the one which considers the immediate changes of use for water.

As a consequence of the transfers, CBT unit ownership patterns have changed significantly during the past three decades. Figure 6-6 illustrates the change in the structure of CBT ownership from 1962 to 1992.

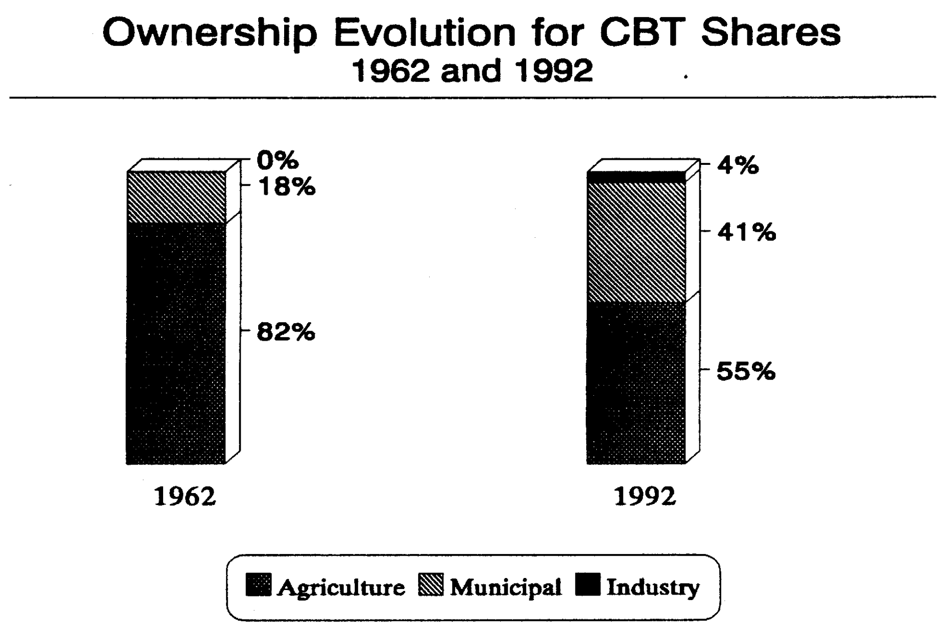


Figure 6-6

In thirty years, municipal holdings more than doubled, from 18 percent of the total to over 40 percent. It is to be noted that industrial holdings were originally included in the municipal holdings, probably explaining the apparent absence of CBT ownership in the industrial sector in 1962. During the same time, the relative quantity of CBT units held by the agricultural sector shrank from more than 80 percent to about 55 percent, which may have an influence on CBT market prices.

Table 6-3: Ten Largest CBT Unit Shareholders (February 1994)

Organization	CBT Units (Total 310,000)	Percent of total
North Poudre Irrigation Company	40,000	12.90
City of Boulder	21,015	6.78
City of Greeley	18,985	6.12
City of Fort Collins	18,699	6.03
City of Loveland	10,355	3.34
Platte Valley Irrigation District	10,320	3.33
City of Longmont	10,148	3.27
Public Service Company	9,997	3.22
Little Thompson Water District	6,594	2.13
Riverside Irrigation District	6,000	1.93
Total	152,113	49.07

Source: Northern Colorado Water Conservancy District.

It is instructive to glance at the current distribution of CBT share ownership of the biggest allottees (Table 6-3).It appears clearly from this table that ownership of CBT units is rather concentrated: half of total units are held by 10 organizations. The concentration in CBT unit ownership is even increasing over time: the typical supplier is an individual or a farm, and the typical acquirer is a municipality, water district, irrigation company or industry. This can lead to a situation where not all market participants have access to the same information nor have balanced negotiating power, resulting in a high price dispersion for different transactions. However, the limited price dispersion in the CBT market suggests that price information is well conveyed and offsets the misbalance of power among negotiating structures.

In conclusion, it can be said that the CBT market constitutes an excellent study case for the purpose of our analysis. This descriptive section has confirmed that most transfers correspond to a change of use from agriculture to municipal and industrial uses. However, transfers among irrigators also occur, even in periods of high prices. The sharp rise in CBT prices around 1980 may indicate the presence of a speculative bubble, but also may be explained by a shift in demand. The following sections focus on factors related to the increase in demand for water.

6.3 Evolution of the value of water in irrigation uses

The review of literature in Chapter Two revealed a high variation in estimates of irrigation water values, calculated by different authors, for different crops, different regions, and at different points in time. It is interesting, however, to take a closer look at the change over time in water values corresponding to the same crop, same region and using the same source of data for consistency. The data series on costs of production for corn in Colorado (*Economic Indicators of the Farm Sector, Costs of Production - Major Field Crops, 1990*, Economic Research Service, U.S.Department of Agriculture) was used to generate the trend in maximum willingness-to-pay for irrigation water. The annual net returns from corn were first deflated using the GNP Implicit Price Deflator. The deflated annual returns were then capitalized into ownership values (water right) using a real discount rate of 5 percent over a 30-year period. The choice of the discount rate and of the period length are both debatable, but the trend in water ownership value would remain the same with different choices. The results are displayed in Table 6-4 and Figure 6-7 in comparison with CBT deflated prices.

Table 6-4: Estimated Ownership Values for Water in Irrigated Corn Production

Year	Net Returns $/Acre (nominal)	GNP multiplier	Net Returns 1992$/Acre	Net Returns 1992$/AF	Capitalized Value 1992$/AF	CBT Price 1992$/AF
1975	67.44	2.461	166.00	76.61	1177.70	1476.83
1976	44.83	2.315	103.80	47.91	736.46	2253.74
1977	52.24	2.166	113.17	52.23	802.92	4338.51
1978	97.71	2.008	196.23	90.57	1392.21	4362.01
1979	114.92	1.846	212.15	97.91	1505.13	5183.67
1980	66.7	1.689	112.66	51.99	799.26	6071.33
1981	28.9	1.535	44.36	20.47	314.70	5077.30
1982	16.94	1.445	24.48	11.30	173.68	3183.09
1983	25.31	1.389	35.15	16.22	249.38	2692.35
1984	42.47	1.329	56.46	26.06	400.54	1683.79
1985	46.89	1.283	60.15	27.76	426.77	1111.79
1986	3.27	1.250	4.09	1.89	28.99	1083.11
1987	23.97	1.211	29.03	13.40	205.94	1235.22
1988	109.26	1.166	127.35	58.78	903.50	1215.27
1989	59.97	1.117	67.00	30.92	475.32	1336.12
1990	63.68	1.070	68.12	31.44	483.32	1852.87

Note: Capitalization at 5 percent discount rate, over 30 years; assumption of 26 acre-inches of water applied per acre of corn.

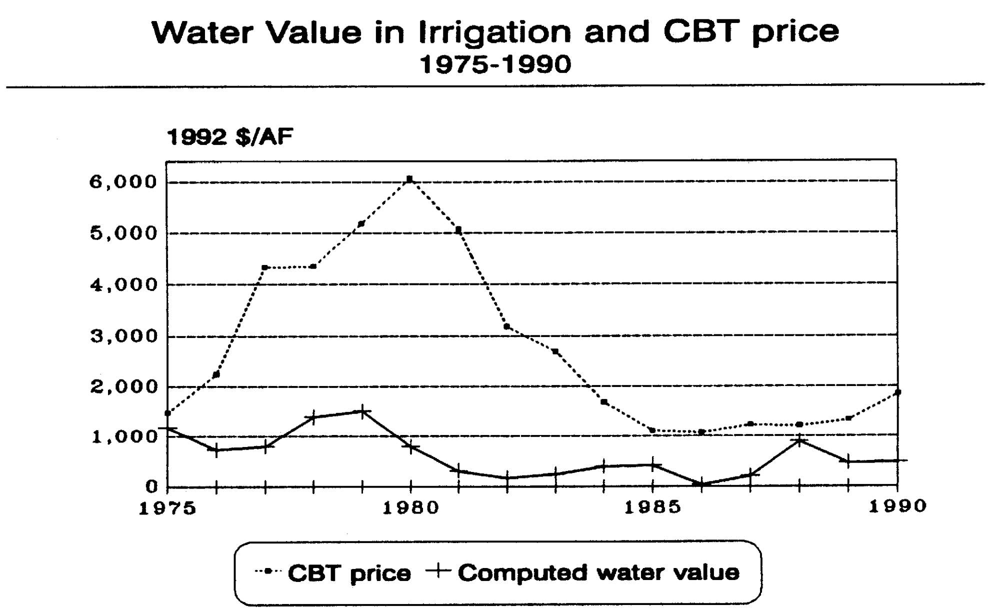


Figure 6-8

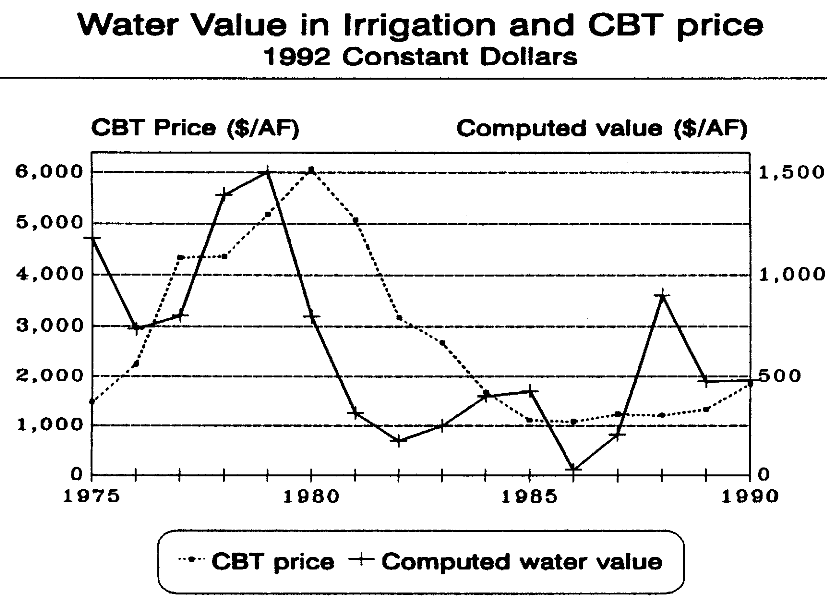


Figure 6-8

From the divergence in CBT prices and a computed irrigation value of water, it appears that returns earned from corn, the dominant crop in the region, do not explain the level of CBT unit prices after 1975. This is consistent with the results obtained by Gardner and Miller (1983). It is interesting to note that prior to the sharp increase in CBT prices, market price and computed value seemed to be close to each other. Subsequently, market price diverged from the computed agricultural value and never came down to the same level. This tends to suggests speculation on behalf of farmers when they were purchasing CBT units at their highest prices. However, the trend in the value of water in irrigation contains another interesting feature. Figure 6-8 shows the same series as Figure 6-7, but on two different vertical axes instead of one. The striking characteristics of this graph are the overall parallel nature of the curves and, in particular, the drop in irrigation value one year before the drop in CBT market price. Similarly, the increase in returns from irrigated corn in the late 1980's occurred before CBT market prices showed an increase. This suggests that returns from irrigated crops may constitute one of the factors that may help explain water right price evolution, but do not adequately explain the price level. Consequently, the price of a water right can be said to contain a second element, based on the willingness-to-pay for water in municipal uses. The next section provides more insight on the potential factors that drive this second element of water right prices.

6.4 An overview of selected demand and supply factors

As discussed earlier, a succession of years with low crop yields and/or prices may lead to the deterioration of farms' financial health. A higher debt-to-asset ratio would be expected to decrease the demand for additional water rights from farmers or to increase the supply of water rights on the market in an effort to reduce the burden of debt. Therefore, let us review the evolution of farm debt-to-asset ratio in Colorado (Figure 6-9).

Although Figure 6-9 suggests that financial health of Colorado farms has improved since 1960, this graph does not display any strong relationship between debt-to-asset evolution and CBT prices. During the same time, CBT prices have increased overall, suggesting the existence of the expected negative relationship between debt-to-asset ratio and water right prices. However, the peak in CBT prices in 1980 is not reflected by a corresponding "valley" in the debt-to-asset ratio.

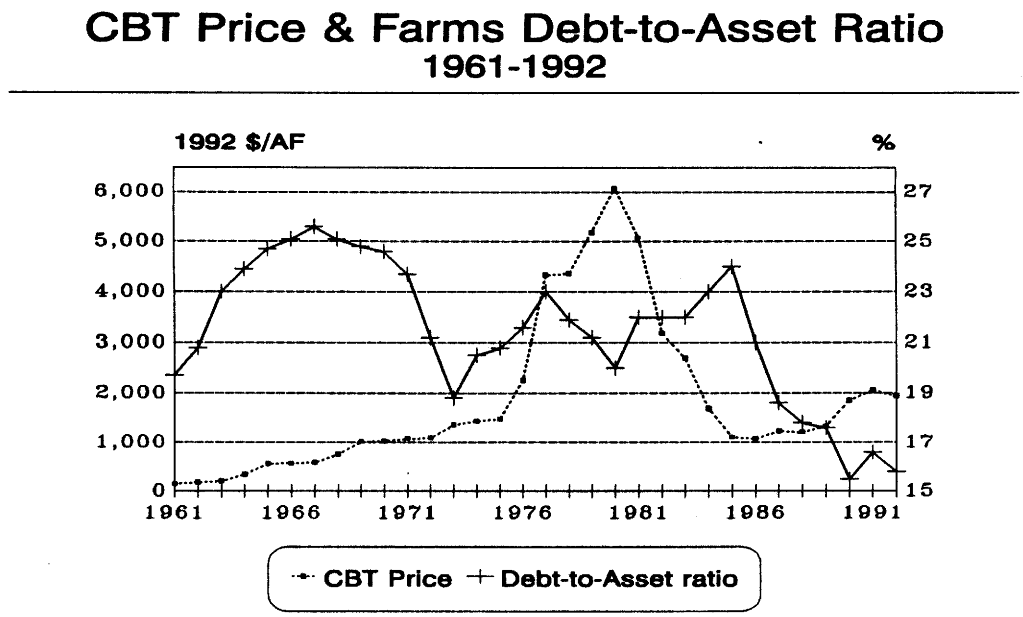


Figure 6-9

Population was hypothesized to have a strong influence on the course of water right prices. Figure 6-10 shows the change in population in Boulder, Larimer and Weld Counties altogether, both in terms of absolute value and annual net variation.

This graph illustrates high population growth in the early 1970's, which may have led to increased demand pressure on water right markets. In the same way, the decreasing population growth in the second half of the 1970's appears as a precursor to the downturn in CBT prices (which started in 1981). Consequently, the net annual change in population appears to have had some influence on CBT price variation.

Related to population change is the number of housing starts authorized by building permits. The major cities in the NCWCD service area require that applicants

Population in Boulder, Larimer and Weld Counties 1960-1992

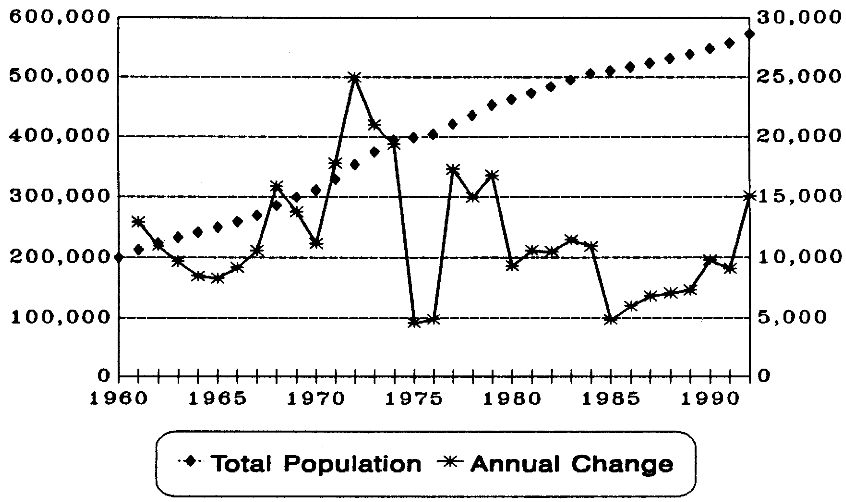


Figure 6-10

for building permits acquire the needed water rights prior to the permit issuance. For this reason, it is believed that this factor may provide useful information regarding CBT price variation. The number of housing starts reflects the commitment to supply water and includes other elements such as inflation rate, cost of money, confidence in the future, etc. Figure 6-11 shows the annual number of housing starts for Boulder, Larimer and Weld Counties and annual CBT prices.

Although the pattern for housing starts is highly cyclical, the long-run trend is obviously related to the change in population, which is expected. Again, with the observed patterns of increasing until the early 1970's, then decreasing until the early 1980's and increasing again after 1985, the number of housing starts seem to precede

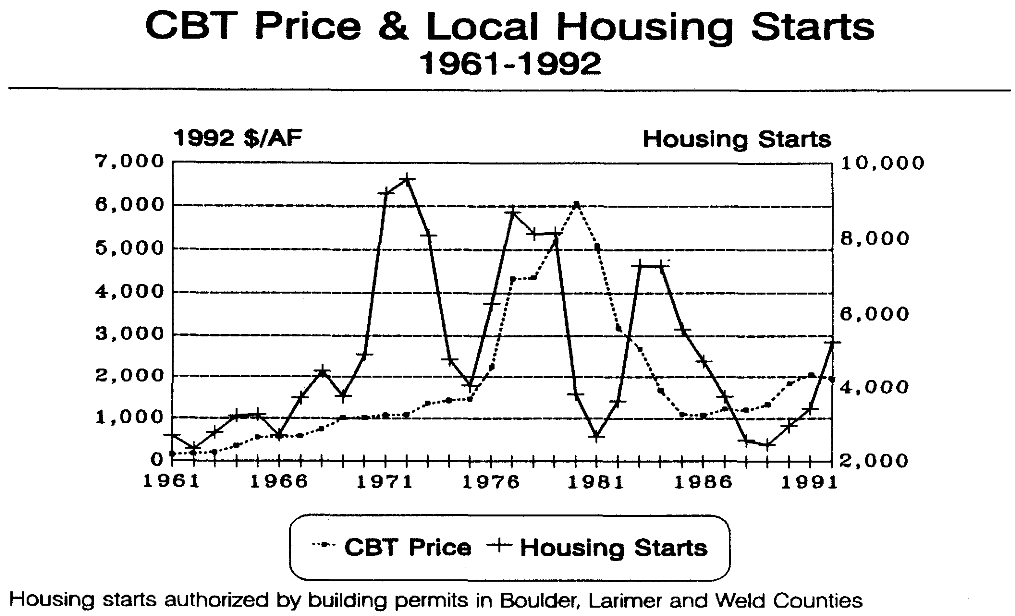


Figure 6-11

changes in CBT prices. Both population changes and the variation in housing starts seem to play an important role in people's expectations of future economic growth and demand for water.

Per capita income in the region has increased almost linearly over the past few decades (Figure 6-12), doubling in thirty years. However, the annual variation in income displays an interesting trend. The annual net growth in per capita income increased until the late 1970's and dropped around 1980. Based on just anecdotal evidence, the change in per capita income also seems to have influenced the change in CBT prices.

To summarize, the sharp increase in CBT prices appears as an "after-shock"

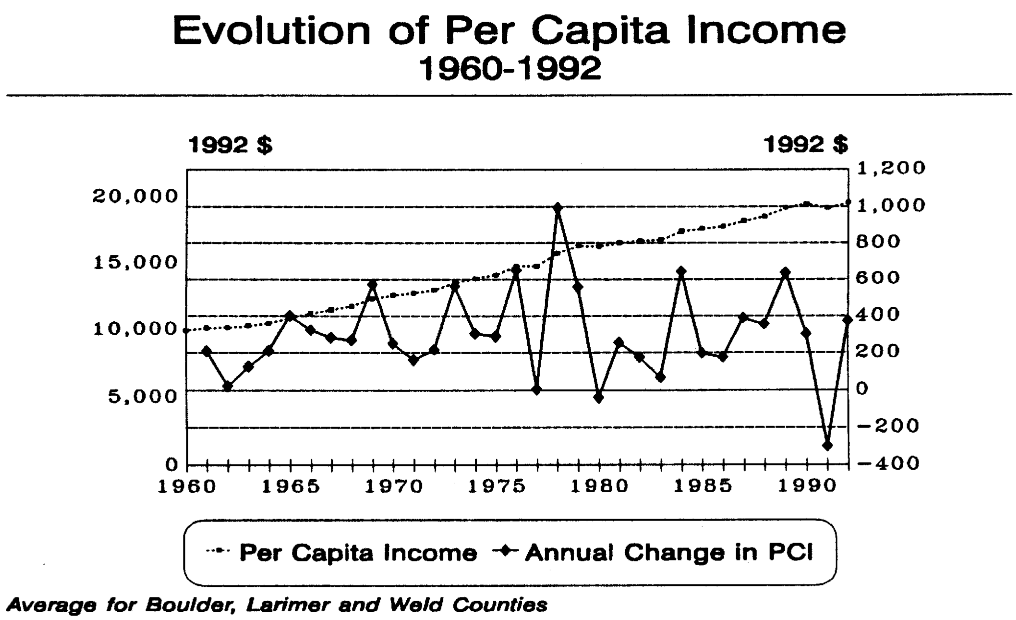


Figure 6-12

increase due to a structural, real increase in demand (e.g., population and housing starts). It was probably based on the expectation that this increased demand would last longer in time, or would have longer effects on CBT prices. The evolution in per capita income may help to explain the downturn in CBT prices in 1980-81.

As explained in Chapter Three, inflation and interest rates are expected to influence the demand for water, and consequently water right price evolution. The trends in inflation and nominal prime rates are given in Figure 6-13, and Figure 6-14 displays the evolution in real prime rate along with CBT prices. Given that these series (except the price series) are inter-related, it is not surprising that they exhibit the same general pattern. Nominal interest rates seem to be a fairly adequate indicator

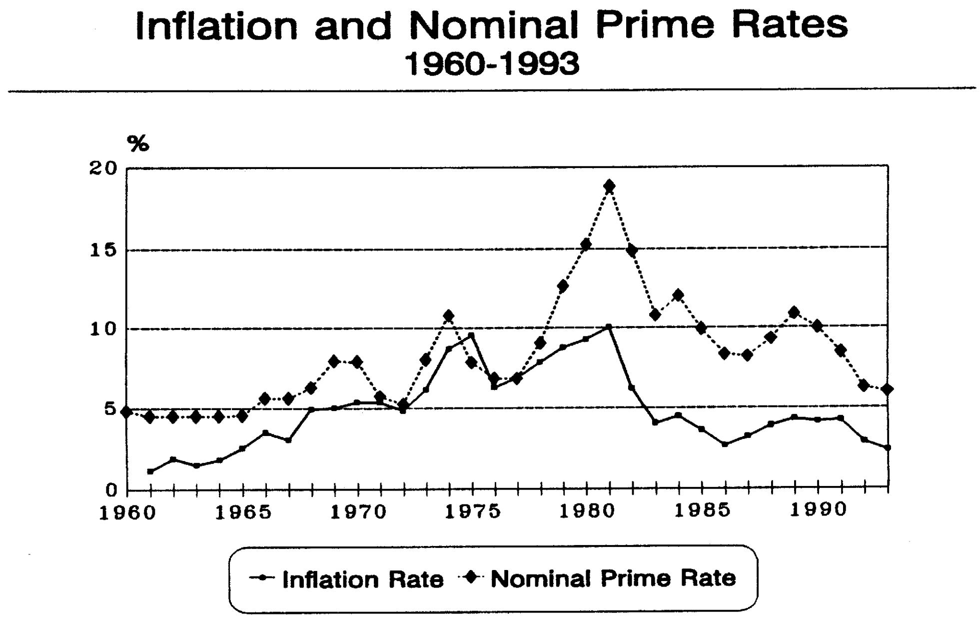


Figure 6-13

of contemporaneous CBT price changes. Inflation and real prime rates may partly explain the variation in CBT prices. For example, Figure 6-14 shows that the real prime rate was at its lowest level when CBT prices began to increase sharply around 1975, providing incentive for investment. Similarly, in 1981, when CBT prices started decreasing, the real prime rate was at its highest value. It is not until the prime rate declined in the late 1980's and early 1990's that CBT prices started to increase again. Therefore, inflation and real interest rates appear to constitute potential determinants for CBT prices. This provides evidence that water rights are considered as investment assets.

Because water rights are perpetual property rights, that is, purchases are

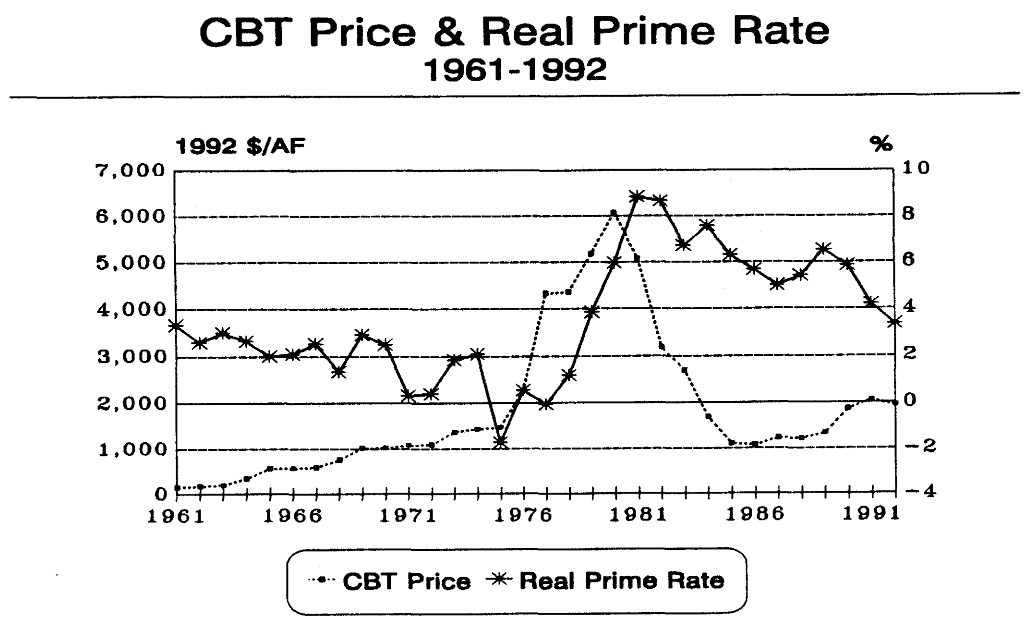


Figure 6-14

probably not based on temporary needs, annual variation in precipitation are not expected to play a significant role in the determination of water right prices. A possible exception may appear during actual or perceived extended periods of drought. The local precipitation data for the NCWCD area is displayed in Figure 6-15. The relationship between precipitation and CBT prices is unclear. However, a significant increase in precipitation occurred just before the downturn in CBT prices, possibly suggesting that, with increased water supplies, market participants may have decided to delay investments in water rights. This situation may have contributed to decreasing the pressure on the market.

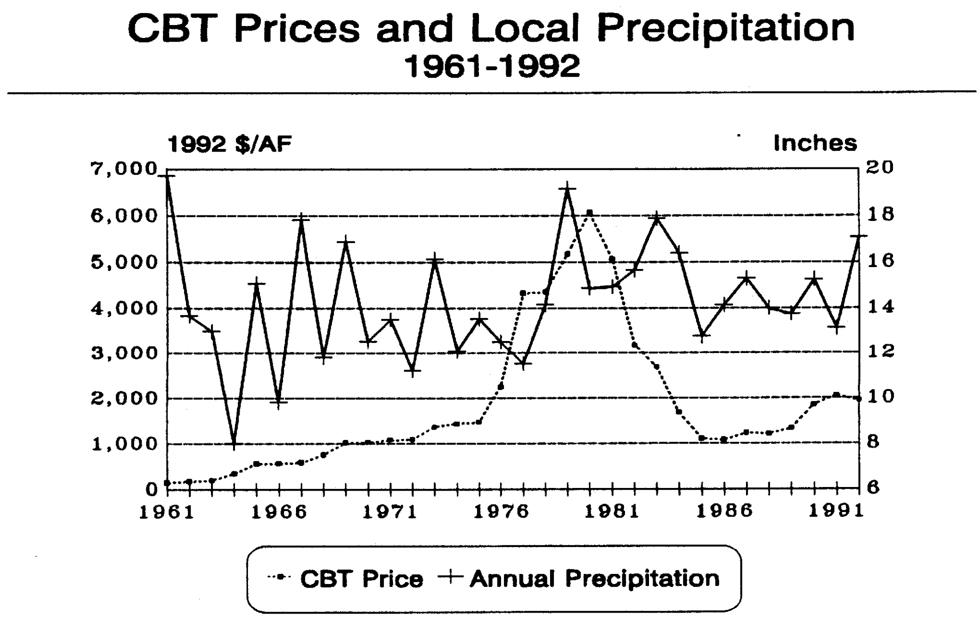


Figure 6-15

6.5 Prices of CBT units and of other natural resources

Comparing the price evolution (in constant terms) of CBT water rights with that of oil, farmland, silver and gold proved interesting. These price evolutions are depicted in Figures 6-16 through 6-19. All price trends are very similar, which suggests that they may be under the influence of the same, or similar, factors.

The price of crude oil followed a trend similar to that of CBT units over the past three decades. Oil is a speculative commodity, and the oil market has been subject to a variety of supply pressures, especially in the second half of the 1970's. The crisis initiated by the Organization of Petroleum Exporting Countries resulted in a temporary decrease in the world's oil supply. Plus, a widespread concern that the

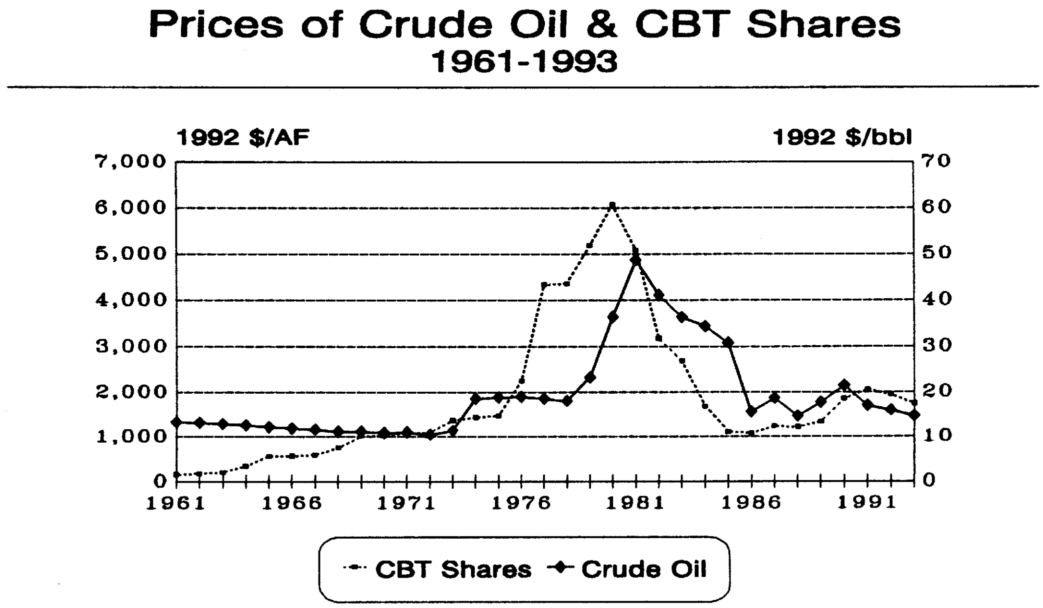
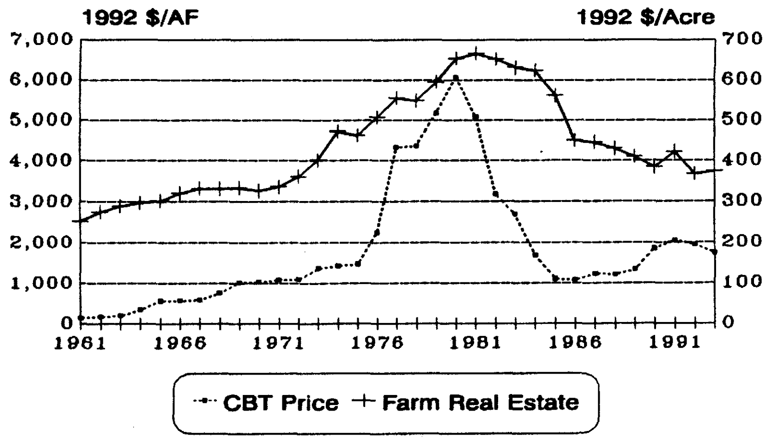


Figure 6-16

world was running out of energy sources was particularly acute at that time, contributing to the support of high price levels. Adelman (1975) writes: "The world 'energy crisis' or 'energy shortage' is a fiction. But belief in the fiction is a fact. It makes people accept higher oil prices as imposed by nature, when they are really fixed by collusion." Quite interestingly, the perception of "water shortage" or "water crisis" also became important in the western United States in the late 1960's and 1970's (Hartman and Seastone, 1970). In other words, both oil and water right prices seem to have exhibited, at the same time, an expectational element. Other factors have probably influenced the evolution of oil prices, such as inflation and interest rates. These factors may also have played a major role in the determination of farm real estate, silver and gold prices. As shown in Figures 6-15, 6-17 and 6-18, these

Prices of CBT Units & Farm Real Estate
1961-1993



Prices of Farmland & Buildings for Colorado (ERS, USDA)

Figure 6-17

latter investment commodities exhibit price trends similar to that of CBT units. A correlation analysis was performed to study the correlation between CBT unit, oil, farm real estate, silver and gold prices. The results are described in Table 6-5. The farm real estate price series has the highest correlation with the CBT unit price series (0.811), followed by silver prices (0.795), oil prices (0.662) and then gold prices (0.587). It appears that oil and real estate prices are highly correlated (0.874), as are silver and gold prices (0.905).

Given that these commodities are hypothesized to be investment goods, they probably share some common determinants related to investment decisions. For this reason, each of these commodities' price series was regressed on inflation and real interest rate (prime rate). Table 6-6 contains the results of the regression analysis.

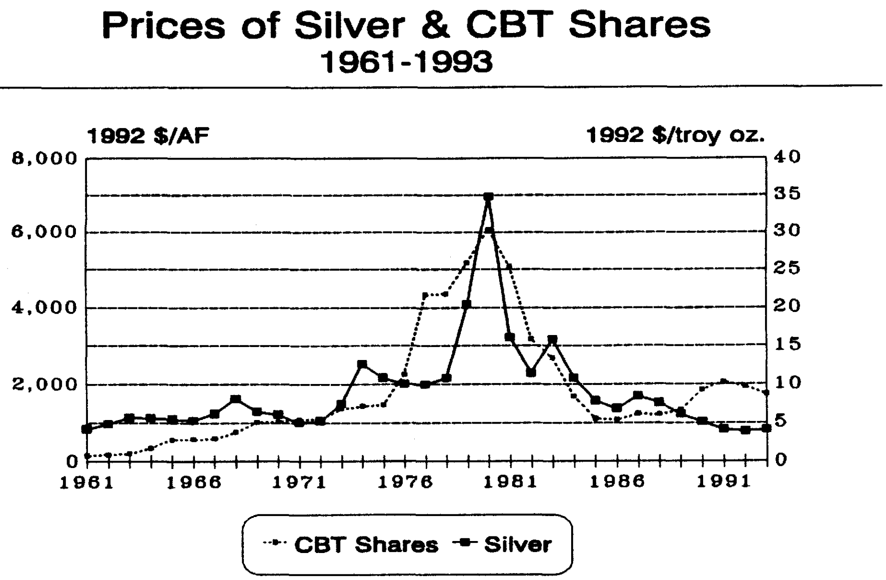


Figure 6-18

Table 6-5: Matrix of correlations between the Prices of CBT shares, farm real estate, crude oil, silver and gold, 1961 to 1992 (constant 1992 $).

Variables	CBT	Estate	Oil	Silver	Gold
CBT	1.000	-	-	-	-
Real Estate	0.811	1.000	-	-	-
Oil	0.662	0.874	1.000	-	-
Silver	0.795	0.733	0.646	1.000	-
Gold (1)	0.587	0.609	0.628	0.905	1.000

(1): 1977 to 1993 only.

It appears from the results in Table 6-6 that serial correlation may be a problem in regressing these series of annual prices (rho is significant in most cases), thus justifying the use of an autoregressive approach. The coefficient associated with the inflation rate used alone as an independent variable is always significant, which is

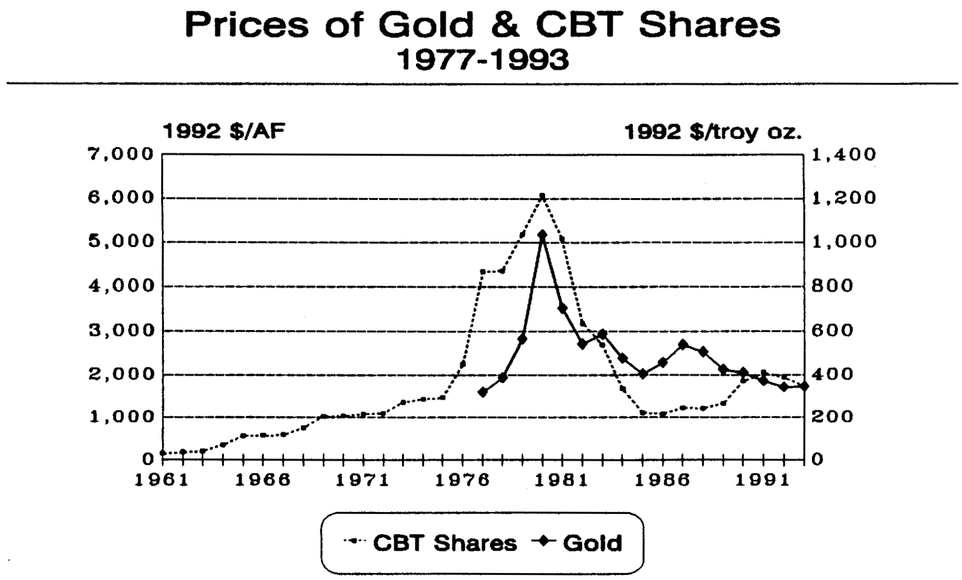


Figure 6-19

not the case for the prime rate. However, the prime rate can usually add some information when used with inflation, reflected by a higher R-square associated with both independent variables. Such a model seems to be appropriate for explaining the variations in CBT unit prices, farm real estate prices and oil prices. This suggests that these commodities, including CBT water rights, can be regarded as investment goods, and can at the same time be adequately explained by inflation and real interest rates. However, based on the R^2, the fit is not as good for the precious metals, suggesting that one or more explanatory factors are missing in the model.

Table 6-6: Results of the Regression (Autoregressive Procedure) of Selected Natural Resources' Prices on Inflation and Real Prime Rates (1961 to 1993).

Dependent Variable	Rho	Constant	Inflation Rate	Real Prime Rate	R^2
CBT	0.874 ***	815.10	190.71 **		0.854
	0.903 ***	1363.2		42.28	0.8332
	0.868 ***	679.3	191.19 **	38.88	0.855
Real Estate	0.951 ***	337.35 ***	10.113 **		0.927
	0.956 ***	331.88 ***		9.168 **	0.928
	0.947 ***	309.40 ***	9.727 **	8.822 **	0.937
Oil	0.870 ***	10.62 *	1.783 ***		0.810
	0.813 ***	11.90 ***		1.759 ***	0.814
	0.727 ***	4.058	1.755 ***	1.873 ***	0.866
Silver	0.371 **	1.77	1.466 ***		0.534
	0.644 ***	7.42 **		0.291	0.443
	0.136	-1.83	1.673 ***	0.732 **	0.585
Gold (1)	0.247	286.65 **	39.15 **		0.395
	0.423 **	340.95 ***		28.88	0.351
	-0.130	94.72	42.25 ***	34.69 **	0.569

(1): 1977 to 1993. Level of significance: * $\alpha = 0.10$; ** $\alpha = 0.05$; *** $\alpha = 0.01$.

6.6 Conclusion

Prices of CBT shares have fluctuated a lot since the corresponding market was established. The succession of very long runs (positive and then negative) during the period 1961-1985 suggests the possibility for a speculative bubble to have developed at that time. Returns to water in agricultural production when examined graphically appear to explain part of the variation CBT price but not the price level after 1975. Other factors were described that may help to explain CBT price variation and level: population, housing starts, per capita income, as well as "investment" factors such as inflation and real interest rates. Finally, the striking parallel between the prices of

CBT units and the prices of other natural resource commodities were examined with fair success by considering their investment asset properties.

CHAPTER SEVEN: ECONOMETRIC ANALYSIS OF CBT PRICES

7.0 Introduction

The econometric analysis integrates the previous model and data developments and applies them to the CBT water right market as a test of the proposed hypotheses. The primary objective is to better understand the relationships between potential price-influencing factors and CBT water right prices. First, the polynomial distributed lag composite variables are presented, as well as their distribution in the system equations. Potential multicollinearity among the composite variables present in each equation is analyzed through variance-decomposition proportions tests. The results of the model estimation using a Three-Stage Least Squares procedure are then presented and interpreted. Finally, the reliability of the model and its ability to produce accurate forecasts are examined.

7.1 The specific model

As discussed in Chapter Three, the proposed model of water right price determinants consists of two equations, each of which is given a specific role. The price expectation equation is intended to capture the effects of predictable, long-term effect variables from which market participants can generate future price expectations. The current price equation integrates the fitted value from the first equation, the CBT price history and more immediate variables in order to account for short-term fluctuations. The specification of variables (which were described in Chapter Five) in each equation is as follows:

CBT Price Expectation= f(CBT Price History, Population*, Per Capita Income*, Building Permits*, Inflation Rate*, Real Prime Rate*, Debt-to-Asset Ratio*, CBT Agricultural Holdings, Windy Gap Dummy Variable);

note: * including the variable's history

Current CBT Price= g(CBT Price Expectation, CBT Price History, Previous year's Corn Gross Revenue per Acre, Relative Acquisitions made by Municipal Sector in current year, Average Precipitation over current and four past years).

where f and g are linear functions.

Historical variable values were included from year t-1 to year t-4. However, given the length of the data set (33 total observations, reduced to 28 with the lag structure) and the existence of correlation among some of the pre-determined variables, it was decided to minimize the number of variables. This was done in order to keep as many degrees of freedom in the model as possible and to reduce the chances for collinearity among variables.

Population and per capita income were combined into one single variable (population times per capita income) which measures the total income, and provides a good proxy for the regional economic growth. Also, only the current value of CBT agricultural holdings was included in the model. This is justified by the fact that agricultural CBT unit holdings declined almost linearly over the study period, and therefore the benefit of including the variable's own history seemed limited compared to the cost in degrees of freedom and potential collinearity. Similarly, information about the local precipitation was included as one variable: the average precipitation for the current and the four most recent years. This special treatment was justified by the fact that, in a succession of dry years, the level of precipitation in the recent years contributes as much to the water supply and perception of drought as the current year's rainfall. Therefore, by taking an average, the same weight was given to the precipitation in the current and the four most recent years.

For better modeling accuracy, two variables were refined and deserve attention. The number of housing starts is one of them. The major cities in the NCWCD generally require that building permit applicants acquire the necessary raw water rights prior to filing their applications. Therefore, in reality, at least one year passes between the time of water purchase and the time of initiating the construction. For this reason, the first year of building permits to be considered by the model is not year t, but year t+1, which is given full weight. The full lag structure thus includes years t+1 through t-4. This longer structure may help to decompose the highly cyclical trend in the number of housing starts (refer to Chapter Six) in order to better capture its long-term effect on CBT prices. The second of these variables is the corn gross revenue per acre. Given the harvesting and selling time periods for this summer crop, the gross revenue (yield times price per unit) is unknown until the end of the year and therefore should not affect that year's CBT price. This is why this explanatory variable is lagged one year.

Finally, the contribution of the Windy Gap project to CBT price evolution was incorporated in the model through the use of a dummy variable, whose value is zero prior to 1980 and one from 1981 to 1992. As described earlier, the settlement agreement for the project was signed in April 1980, solidifying the commitment to construct the reservoir, increasing the water supply to the region.

The general construction of the model is described below, as well as the variable names used for estimation.

Price Expectation

$$PE_t = f(\sum_{i=1}^{4} w_{i1}P_{t-i}, \sum_{i=0}^{4} w_{i2}POPCI_{t-i}, \sum_{i=-1}^{4} w_{i3}BLD_{t-i}, \sum_{i=0}^{4} w_{i4}INFL_{t-i}, \sum_{i=0}^{4} w_{i5}RATE_{t-i}, \sum_{i=0}^{4} w_{i6}DEBT_{t-i}, AGHP_t, WGAP)$$

Current Price

$$P_t = g(\hat{PE}_t, \sum_{i=1}^{4} w_{i7}P_{t-i}, CORN_{t-1}, MUNBUY_t, PRECM_t)$$

where $PE_t = E_t(P_{t+1})$ = expectation of the CBT price in year t+1, formulated in year t,

P= CBT price (1992 $/AF),

POPCI= population times per capita income, and represents the regional economic growth (1992 $),

BLD= housing starts authorized by building permits,

INFL= annual inflation rate (%),

RATE= annual real prime interest rate (%),

DEBT= farm debt-to-asset ratio (%),

AGHP= agricultural CBT unit holdings (units),

WGAP= dummy variable for the Windy Gap project,

CORN1= corn gross revenue lagged one year (1992 $/Acre),

MUNBUY= relative CBT acquisitions by the municipal sector (%),

PRECM= five year average precipitation (inches),

w_i= lag weight, period i, variable 1-7,

t= time (year),

i= time index taking on the values of 0 through 4,

and f and g are linear functions.

The model presented above constitutes the primary model to be estimated. For estimation purposes, a polynomial distributed lag of degree one (linear structure) is integrated by generating two variables per factor as explained in Chapter Three. These composite variables have the same name as the original variables, preceded by a P. For example, regional economic growth is represented by PPOPCI and PPOPCI1, housing starts by PBLD and PBLD1, etc. By imposing a constraint during the estimation so that the weight on year t-5 be equal to zero, a linearly declining weight is given to current (full weight) and past observations until t-4. The advantage of this structure is that it adequately represents what we believe are the true effects of past information on water right price formation. It is also relevant because it reduces the loss of degrees of freedom in the model, and at the same time facilitates interpretation of the results (current and past observations for each variable have the same sign).

7.2 Multicollinearity

Multicollinearity appears when two or more variables (or combination of variables) are highly, but not perfectly, correlated with each other (Pindyck and Rubinfeld, 1991). When this is the case, Ordinary Least Squares parameter estimates can still be calculated and remain unbiased, but they are less reliable because their variances and covariances increase (Wallis, 1972). Plus, the regression coefficient of any pre-determined variable then depends on which other correlated pre-determined variables are included in the model (Neter *et al.*, 1989).

The set of variables actually present in each equation, plus a column of ones that represents the intercept (called INT), were tested for multicollinearity - or near dependency - using variance-decomposition proportion tests (Belsley, 1991). However, given the restriction put on the model during the estimation procedure that imposed a zero weight on year t-5 for each lagged variable (see Chapter Three), near dependencies among variables in the model could be best measured by including only one of the two composite variables per lagged factor in the tests. Indeed, with such a restriction in the model, only one coefficient is effectively estimated for each lagged factor. The coefficient associated with the first combined variable (for each lagged factor) in fact determines both the intercept and the slope of the linear lag, subject to the restriction. Therefore, the coefficient associated with the second composite variable is determined by the first one, for each lagged factor. The results are summarized in Tables 7-1 through 7-4.

The variance-proportion decomposition test can be briefly described as follows. First, principal components are extracted from the scaled cross-product data matrix (scaled means transformed so that all diagonals are equal to one). To each principal component corresponds a condition number, normalized into a condition index for interpretation purposes, which indicates the closeness of near dependencies among variables. The higher the condition index, the higher the correlation between some or all of the variables. Variance-decomposition proportions give the involvement of individual variables in each collinear relationship.

Following Belsley (1991), scaled condition indexes were considered high, i.e. revealing the presence of near dependencies, if greater than 30. A variable was considered involved in one or more near dependency if the sum of its variance-decomposition proportions across the coexisting near dependencies was higher than 0.5. Table 7-1 shows the existence of three near dependencies in the data set used in the price expectation equation. One of these near dependencies is dominant with a scaled condition index of 498.6, and involves the intercept (INT), the composite variable representing economic growth (PPOPCI) and agricultural CBT holdings (AGHP). These variables can be said to be strongly collinear with each other, and the corresponding coefficients can be expected to be affected. The second near dependency (condition index of 86.9) reveals only the obvious involvement of PDEBT

Figure 7-1: Scaled Condition Indexes and Variance-Decomposition Proportions for the Price Expectation Equation, Intercept Included

Condition Index	Proportion of								
	INT	PP1	PPOPCI	PBLD	PINFL	PRATE	PDEBT	AGHP	WGAP
1.0	0.0000	0.0004	0.0000	0.0001	0.0001	0.0003	0.0000	0.0000	0.0003
3.1	0.0000	0.0001	0.0000	0.0006	0.0003	0.0044	0.0001	0.0000	0.0161
4.7	0.0000	0.0605	0.0000	0.0000	0.0020	0.0032	0.0003	0.0000	0.0000
10.3	0.0000	0.0708	0.0042	0.0092	0.0046	0.0468	0.0014	0.0001	0.0105
17.2	0.0001	0.0676	0.0086	0.0863	0.0069	0.1033	0.0000	0.0002	0.0070
24.7	0.0000	0.0225	0.0154	0.0023	0.0101	0.4131	0.0017	0.0005	0.8775
43.4	0.0000	0.6643	0.0010	0.2849	0.8337	0.2953	0.0170	0.0001	0.0794
86.9	0.0039	0.1075	0.0094	0.2510	0.1416	0.1078	0.9612	0.0175	0.0005
498.6	0.9959	0.0062	0.9613	0.3655	0.0006	0.0258	0.0182	0.9816	0.0083
Affected Variables	*	*	*	*	*		*	*	

Table 7-2: Scaled Condition Indexes and Variance-Decomposition Proportions for the Price Expectation Equation, Intercept Excluded

Condition Index	Proportion of							
	PP1	PPOPCI	PBLD	PINFL	PRATE	PDEBT	AGHP	WGAP
1.0	0.0006	0.0006	0.0002	0.0001	0.0003	0.0000	0.0000	0.0004
2.9	0.0000	0.0009	0.0011	0.0005	0.0045	0.0001	0.0002	0.0164
4.5	0.0652	0.0009	0.0000	0.0016	0.0037	0.0005	0.0009	0.0000
9.7	0.0690	0.1349	0.0128	0.0045	0.0506	0.0016	0.0024	0.0108
16.9	0.0670	0.3778	0.1309	0.0069	0.0925	0.0005	0.0112	0.0156
23.2	0.0205	0.4159	0.0059	0.0099	0.4496	0.0030	0.0165	0.8769
40.7	0.6722	0.0299	0.4288	0.8375	0.3020	0.0169	0.0042	0.0798
86.4	0.1054	0.0389	0.4202	0.1389	0.0971	0.9773	0.9645	0.0001
Affected Variables	*		*	*		*	*	

(composite variable for the farm debt-to-asset ratio), but the involvement of other

Table 7-3: Scaled Condition Indexes and Variance-Decomposition Proportions for the Current Price Equation, Intercept Included

Condition Index	Proportion of					
	INT	PF	PP1	CORN1	MUNBUY	PRECM
1.0	0.00008	0.00445	0.00266	0.00148	0.00471	0.00008
3.5	0.00027	0.08097	0.08204	0.00021	0.11716	0.00020
5.4	0.00015	0.51948	0.13840	0.00511	0.05259	0.00060
6.1	0.00109	0.00643	0.14846	0.08097	0.49332	0.00045
13.6	0.01358	0.05359	0.00655	0.81172	0.32954	0.01780
68.5	0.98484	0.33507	0.62188	0.10051	0.00269	0.98087
Affected Variables	*		*			*

Table 7-4: Scaled Condition Indexes and Variance-Decomposition Proportions for the Current Price Equation, Intercept Excluded

Condition Index	Proportion of				
	PF	PP1	CORN1	MUNBUY	PRECM
1.0	0.00994	0.00979	0.00263	0.00693	0.00175
3.2	0.09984	0.18263	0.00091	0.17227	0.00480
4.9	0.78003	0.38750	0.00427	0.01527	0.00975
5.8	0.00095	0.31973	0.17562	0.41408	0.02022
14.3	0.10924	0.10034	0.81657	0.39145	0.96348
Affected Variables					

variables is probably masked by the dominance of the first near dependency. The third near dependency (condition index of 43.4) clearly involves PP1 (composite variable for CBT price history) and PINFL (composite variable for inflation rate), which could be expected from the descriptive analysis. The composite variable PBLD (for housing starts) never has more than 50 percent of its variance associated with one single near dependency, but 90 percent of its total variance is distributed among the set of high condition indexes. This suggests that the coefficient associated with PBLD will also be affected by the collinear relationships. As summarized in the bottom of Table 7-1, only two variables are unaffected by multicollinearity: PRATE (composite variable for prime rate) and WGAP (dummy variable for the Windy Gap project).

The choice of incorporating the intercept (as a column of ones) in the collinearity tests is sometimes argued upon because this element can introduce near dependencies that did not exist in the original data set. Since in our case both equations contained a constant term, it seemed more appropriate to take it into account in the collinearity test. However, it is interesting to examine the contribution of this intercept to collinear relationships. This is the intent of Table 7-2, which displays the results of the same test, performed without the intercept term. No dominating near dependency appears here, suggesting that it was induced by the intercept. Two obvious collinear relationships are revealed in the original data: PDEBT with AGHP and PP1 and PINFL. Again, PBLD has 85 percent of its variance associated with these near dependencies and is therefore affected by multicollinearity. Consequently, the intercept introduces strong problems of near dependency which involve PPOPCI and AGHP, even masking the collinear relationship between AGHP and PDEBT. The interpretation of the regression results will have to account for these problems.

The current price equation exhibits fewer collinearity problems. As displayed in Table 7-3, one near dependency exists which involves the intercept (INT), the CBT price history (PP1) and the precipitation moving average (PRECM). Here again, the effect of the presence of an intercept is important: once dropped from the test, the collinearity disappears (Table 7-4).

In summary, the study of collinearity reveals the existence of near dependencies among variables, which makes it more difficult to interpret the real contribution of each individual coefficient to CBT price variation. However, the tests reveal that collinear relationships are more numerous and stronger when a column of ones is included to represent each equation's intercept. When this intercept term is dropped from the test, only two near dependencies remain among the price expectation equation's variables, and none among the current price equation's variables. This suggests that, given the short length of the data set used in estimation, the choice of the variables and of the corresponding lag structure introduced as few weaknesses in the econometric analysis as could be anticipated.

7.3 The Three-Stage Least Squares Estimation

Given the presence of the price expectation instrument in the model, efficient and consistent estimates could be obtained using an instrumental-variable technique. A Three-Stage Least Squares procedure was selected, because it accounts for potential residual cross-correlation across equations. The results are displayed in Tables 7-5 and 7-6. First, it can be said that both equations produce a good fit: the R^2 are 94 percent and 93 percent, respectively, for the price expectation equation and the current price equation. Second, it is important to note that both equations are exempt from serial correlation problems, as suggested by the runs test at the bottom of each table. Given that each of the equations contains lagged values of the dependent variable as pre-determined variables, the Durbin-Watson test is not appropriate (Pindyck and Rubinfeld, 1991), and therefore the runs test is considered here. The number of runs is the number of successions of residuals having the same sign. The normal statistic represents the departure (in standard deviations) of the residual distribution from that of a random walk. A value close to zero suggests no autocorrelation pattern in the residuals, whereas a normal statistic of over 2 would generally suggest the need for a correction procedure.

Price expectation equation

The 94 percent R^2 for the price expectation equation (Table 7-5) means that 94 percent of the total variation in the future CBT price is explained by this equation. Only two variables are not significant at the 0.10 level: housing starts and inflation rate. But let us discuss the results for each variable independently. A coefficient can be interpreted, in the absence of multicollinearity, as the effect on the dependent variable (here expected price for CBT units) of a one unit increase in the corresponding pre-determined variable, *ceteris paribus*.

The parameter estimates associated with the CBT own price history are highly significant, and have a positive sign as expected. The contribution of the local economic growth (population times per capita income in Boulder, Larimer and Weld counties) to explaining CBT price variation is also significant, and has a positive

Table 7-5: Regression Results for the Price Expectation Equation - Dependent Variable: PE

Variable Description	Variable Name	Estimated Parameter	Standard Error	T-Ratio
Intercept	INT	-4.072 E+04 *	1.221 E+04	-3.336
CBT Price History	P_{t-1}	0.264 *	0.078	3.376
Mean= 1831.76	P_{t-2}	0.198 *	0.059	3.376
Std Dev= 1545.29	P_{t-3}	0.132 *	0.039	3.376
	P_{t-4}	0.066 *	0.019	3.376
Historical Economic Growth	POPCI	6.452 E-07 *	1.349 E-07	4.782
(Population * Per Capita	$POPCI_{t-1}$	5.161 E-07 *	1.079 E-07	4.782
Income)	$POPCI_{t-2}$	3.871 E-07 *	8.094 E-08	4.782
Mean= 6.287 E+09	$POPCI_{t-3}$	2.581 E-07 *	5.396 E-08	4.782
Std Dev= 2.871 E+09	$POPCI_{t-4}$	1.290 E-07 *	2.698 E-08	4.782
Historical Housing Starts	BLD_{t+1}	0.027	0.045	0.626
Mean= 4880	BLD	0.023	0.037	0.626
Std Dev= 2211	BLD_{t-1}	0.019	0.030	0.626
	BLD_{t-2}	0.014	0.022	0.626
	BLD_{t-3}	0.009	0.015	0.626
	BLD_{t-4}	0.004	0.008	0.626
Historical Inflation Rate	INFL	58.100	49.313	1.178
Mean= 4.953	$INFL_{t-1}$	46.480	39.451	1.178
Std Dev= 2.421	$INFL_{t-2}$	34.860	29.588	1.178
	$INFL_{t-3}$	23.240	19.725	1.178
	$INFL_{t-4}$	11.620	9.863	1.178
Historical Prime Rate	RATE	-175.802 *	50.489	-3.482
Mean= 3.554	$RATE_{t-1}$	-140.643 *	40.391	-3.482
Std Dev= 2.580	$RATE_{t-2}$	-105.481 *	30.293	-3.482
	$RATE_{t-3}$	-70.319 *	20.195	-3.482
	$RATE_{t-4}$	-35.159 *	10.098	-3.482
Historical Farm Debt-to-Asset	DEBT	58.530 *	32.352	1.809
Ratio	$DEBT_{t-1}$	46.824 *	25.881	1.809
Mean= 21.43	$DEBT_{t-2}$	35.118 *	19.411	1.809
Std Dev= 2.75	$DEBT_{t-3}$	23.412 *	12.941	1.809
	$DEBT_{t-4}$	11.706 *	6.470	1.809
Agricultural CBT Holdings Mean= 212,493 Std Dev= 27,553	AGHP	0.129 *	0.045	2.861
Windy Gap dummy 1961-1980: 0 1981-1992: 1	WGAP	-1892.710 *	779.951	-2.427

*: significant at α= 0.10; R^2 = **0.9402.**

Runs Test: 14 Runs, 15 Positive Residuals, 13 Negative Residuals, Normal Statistic = -0.3596

Table 7-6: Regression Results for the Current Price Equation - Dependent Variable: Price

Variable Description	Variable Name	Estimated Parameter	Standard Error	T-Ratio
Intercept	INT	1430.223	0.802	0.429
CBT Price expectation Fitted value from equation 1	PFhat	0.638 *	0.091	7.034
CBT Price history Mean= 1831.76 Std Dev= 1545.29	P_{t-1}	0.232 *	0.050	4.579
	P_{t-2}	0.174 *	0.038	4.579
	P_{t-3}	0.116 *	0.025	4.579
	P_{t-4}	0.058 *	0.013	4.579
Corn gross revenue (lagged one year) Mean= 452.11 Std Dev= 123.08	CORN1	-0.562	0.852	-0.659
Relative CBT acquisitions made by municipal sector Mean= 58.12 Std Dev= 26.71	MUNBUY	3.603	3.276	1.100
Average Precipitation (over 5 years) Mean= 14.32 Std Dev= 2.51	PRECM	-118.261	121.991	-0.969

*: significant at α= 0.10 ;R^2 = **0.9329.**

Runs Test: 15 Runs, 14 Positive Residuals, 14 Negative Residuals, Normal Statistic = 0.0000

influence, as expected. This suggests that economic growth is a significant determinant for water right prices.

The number of local housing starts is also suggested to have a positive influence on CBT price variation. Although it is believed to be highly relevant, the contribution of this variable was not significant in this analysis. The probable reasons for its lack of significance are the following. First, the number of housing starts, although displaying a long-term trend similar to that of CBT prices a few years ahead, is highly cyclical. The cycles seem to get longer as time goes by, which was confirmed by Dennis Bode, of the City of Fort Collins Water and Wastewater Utility (1993). It is possible that the lag structure selected was not long enough to adequately capture the trend component in the number of housing starts. Second, the multicollinearity test indicated the involvement of this variable in three different near dependencies. Consequently, the standard error of the estimated parameter is increased, which reduces its t-ratio and thus its statistical significance.

The inflation rate coefficient has a positive sign, consistent with our expectations discussed in the price determinant identification section. This is also consistent with the parallel observed between inflation and CBT prices noted in the descriptive analysis. The positive influence suggests that a high inflation rate may provide an incentive for investing in durable assets, and work as a price increase accelerator. However, the coefficient in this model is not found to be significantly different from zero, which may well be the result of influencing collinearity, as discussed earlier.

The coefficient associated with the prime interest rate is found to be significant and negative. This is consistent with our expectations, implying that a low real cost of money in the late 1970's may have contributed to an increased pressure of the demand for perpetual water rights.

The farm debt-to asset ratio appears to significantly influence CBT water right prices, but has an unexpected positive sign. The preliminary analysis also tended to suggest the existence of a positive correlation between these variables. A potential reason for this is that the debt-to-asset ratio may be the consequence, but not the cause, of increased asset prices, including water rights, especially if the price increase is contemporaneous to an over-investment trend.

The estimated parameter associated with the relative quantity of CBT units held by the agricultural sector turns out to be significant also, and has a positive sign where a negative relationship was expected. Indeed, the agricultural CBT holdings have decreased almost linearly from almost 260,000 units (out of 310,000) in 1961 to about 171,000 units in 1992. During the same period, the CBT price, in real terms, has increased from $153/AF in 1961 to $1947/AF in 1992. Seen this way, the relationship is negative, and can be expected to remain negative in the future. The estimated positive sign may be a consequence of multicollinearity (variance-decomposition tests showed a strong influence of collinearity on this variable).

The dummy variable included to represent the increase in water supply from the Windy Gap project is significant and its negative sign is consistent with our expectations. It is interesting to note the value of the coefficient: -1,892.7, which can be interpreted as a price drop of almost $1,900 after 1980, due to the increase in the region's water supply. The fact that this variable picks up the effect of other factors is undisputable, as is often the case with dummy variables, but its inclusion in the model is theoretically justified.

In summary, the price expectation equation appears to produce very positive results through its good fit and its overall consistency in coefficient signs. It is remarkable that only two variables are not significant at the $\alpha = 0.10$ level, given the presence of influencing near dependencies among variables.

Current price equation

The current price equation, which is actually the main equation of the model, produces equivalently interesting results. The R^2 is 0.933, which means that more than 93 percent of the total variation in CBT prices is explained by this equation. Here the runs test produced a normal statistic of zero, suggesting that residuals are serially uncorrelated, and at the same time justifying the use of a 3SLS estimation technique.

The coefficient associated with the price expectation fitted value derived from the first equation is significantly different from zero and positive, as expected. This can be interpreted in the following way. An expected CBT price relative increase of one in the following year is likely to drive the current price to increase by 0.6. This stresses the importance of expectations in price determination, when these expectations are based on the evolution of selected indicators.

The contribution of CBT price history to the determination of the current price is comparable to its contribution in the price expectation formation. The associated coefficients are both positive and significant at the $\alpha = 0.10$ level.

The parameter estimate associated with the gross revenue per acre of corn, used as a proxy for the net revenue, cannot be said to be significantly different from zero according to this analysis. Yet, the variance of the estimated parameter should not be inflated by multicollinearity, since this variable did not appear to be involved in any near dependency through the variance-decomposition proportions test. The sign of the coefficient is negative, where a positive sign was expected. A negative sign would suggest that as the revenue per acre of corn increases, the price of a CBT unit decreases, which is not reasonable. However, the relevance of the estimated sign is very limited given that the estimated coefficient is not significantly different from zero.

The two remaining variables, the proportion of CBT acquisitions made each year by the municipal sector and the average precipitation over five years, both exhibit the expected sign but have estimated coefficients which are not significantly different from zero. However, the influence of collinearity on PRECM, as discussed earlier, may explain this coefficient's lack of significance. Overall, only the price components of the current price equation appear to have a significant influence on CBT price variation. None of the factors hypothesized to have a short-term influence on CBT prices yielded estimated parameters which were statistically significant coefficients. Nevertheless, since the presence of these non-significant variables in the model is theoretically justified, and since they are likely to carry some useful information, these variables were retained in the model.

Simulation results

In order to better represent the model's accuracy in simulation, the predicted values produced by the model were compared to the actual price series. This comparison is given in Table 7-7 and Figure 7-1. The results depicted in Figure 7-1 suggest that our model can accurately simulate CBT price variation over the study period.

Table 7-7: Actual and Simulated Values of CBT Unit Prices (1992 $)

Year	Actual	Simulated	Year	Actual	Simulated
1965	568	280	1979	5183	5584
1966	576	667	1980	6071	5381
1967	596	592	1981	5077	4331
1968	761	970	1982	3183	3889
1969	1024	686	1983	2692	2710
1970	1032	904	1984	1683	1888
1971	1088	780	1985	1111	1374
1972	1099	1304	1986	1083	1224
1973	1368	1161	1987	1235	1544
1974	1438	1246	1988	1215	1202
1975	1476	1746	1989	1336	1547
1976	2253	3152	1990	1857	1691
1977	4338	3467	1991	2060	1828
1978	4362	4754	1992	1946	1808

The results from the 3SLS procedure can be summarized as follows. The model appears to provide a good fit to the data, suggesting that included variables adequately contribute to explain CBT price variation. Residuals do not appear to be serially correlated, suggesting that the estimation technique applied produced efficient and consistent parameter estimates. Most signs were consistent with our expectations, which suggests that individual variables' influences were adequately captured by the

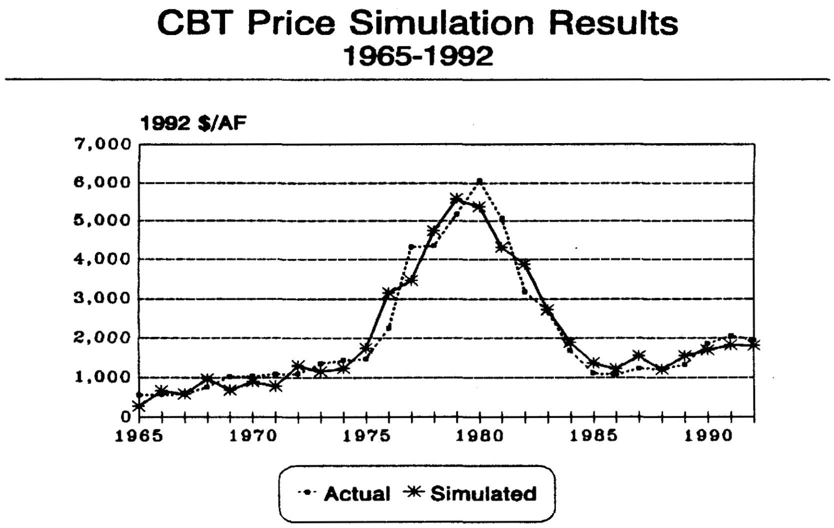


Figure 7-1

model. Since collinearity usually allows a good fit to the sample data but induces poor forecasts, its influence on the model is further tested below through generation of ex-post forecasts.

7.4 Hypotheses testing

Two hypotheses were proposed to be tested through this analysis. The first hypothesis is that water right prices contain a second element besides the irrigation value of water. The second hypothesis proposes that this second element can be adequately explained using socio-economic, market and speculative factors if market participants expectations are also included in the model.

Given that the coefficient associated with the gross revenue per acre of corn was not significant, our first hypothesis was not tested. It was obvious from these results that the price of a CBT unit contains another element besides the return earned in agricultural production. Ironically, this second element appeared to explain most of the CBT price variation. Therefore, our second hypothesis was also implicitly tested: water right prices can be successfully predicted through the use of selected demand, supply and market organization factors, when accounting for potential speculative pressures by incorporating market participants' expectations.

7.5 Prediction accuracy of the model

The accuracy of our model is tested in this section by producing ex-post forecasts and comparing these with observed CBT prices. For this purpose, the same model was estimated a second time using a reduced data set. Given the limited number of observations available, it did not seem reasonable to reduce the data set by more than two years. Therefore, the model was re-estimated using the same data set reduced by one year first (1961-1991) and subsequently by two years (1961-1990).

One-year ex-post forecast

An ex-post forecast was generated for 1992 using the results of the model estimated for the 1961-1991 period. The simulation and forecast results are presented in Table 7-8 and Figure 7-2.

It appears that the simulation was once again fairly accurate, however beyond one forecast period, the forecast was less accurate. A commonly used statistic for evaluating prediction performance is the Theil's inequality coefficient (Pindyck and

Rubinfeld, 1991). This coefficient is calculated using the following formula:

$$U = \frac{\sqrt{\frac{1}{T}\sum_{t=1}^{T}(Y_t^s - Y_t^a)^2}}{\sqrt{\frac{1}{T}\sum_{t=1}^{T}(Y_t^s)^2} + \sqrt{\frac{1}{T}\sum_{t=1}^{T}(Y_t^a)^2}}$$

where Y^s_t = simulated value of Y_t

Y^a_t = actual value

T = number of periods in the simulation.

Table 7-8: Simulation and One-Year Ex-Post Forecast of CBT Prices

Year	Actual	Simulated	Year	Actual	Simulated	Forecast
1965	568	285	1979	5183	5617	-
1966	576	607	1980	6071	5353	-
1967	596	572	1981	5077	4287	-
1968	761	920	1982	3183	3885	-
1969	1024	715	1983	2692	2719	-
1970	1032	897	1984	1683	1884	-
1971	1088	819	1985	1111	1398	-
1972	1099	1286	1986	1083	1248	-
1973	1368	1157	1987	1235	1458	-
1974	1438	1203	1988	1215	1208	-
1975	1476	1724	1989	1336	1546	-
1976	2253	3205	1990	1857	1717	-
1977	4338	3494	1991	2060	1823	-
1978	4362	4738	1992	1946	-	3045

Theil's Inequality Coefficient for Ex-Post Forecast = 0.219

By definition, the Theil's inequality coefficient will always be between 0 and 1. A

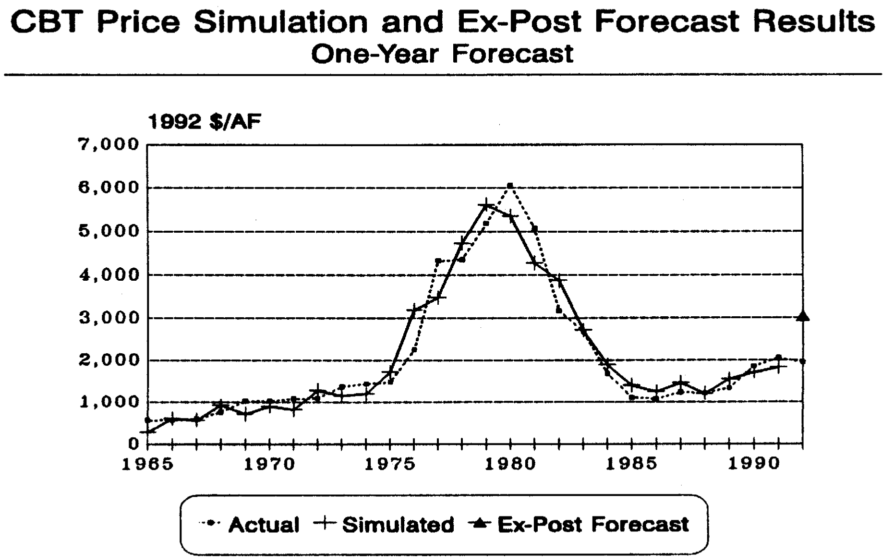


Figure 7-2

zero value is the result of a perfect fit, whereas a value of one denotes a predictive performance of the model not better than a "naive" no-change model (where the forecast for Y_t is simply supposed to be equal to the observed value for Y_{t-1}). In our case, Theil's statistic is rather small, suggesting that the forecasting ability of the model would be acceptable, and more accurate than a "naive" model.

However, Figure 7-2 exhibits an important difference between the actual CBT price in 1992 and the ex-post forecast. There appears to be a turning point in 1991 that is not forecasted by the model. Before discussing the potential reasons for this apparent lack of accuracy, let us perform the same test on a two-year instead of one-year period.

Two-year ex-post forecast

Ex-post forecasts are produced for 1991 and 1992, in a dynamic setting: actual data are used for all pre-determined variables in 1991 to produce a prediction of 1991 CBT price. This result is used as a pre-determined variable when estimating the 1992 ex-post forecast. The results of the reduced simulation and two-year ex-post forecasts are given in Table 7-9 and Figure 7-3.

Table 7-9: Simulation and Two-Year Ex-Post Forecast of CBT Prices

Year	Actual	Simulated	Year	Actual	Simulated	Forecast
1965	568	269	1979	5183	5591	-
1966	576	613	1980	6071	5349	-
1967	596	573	1981	5077	4300	-
1968	761	920	1982	3183	3887	-
1969	1024	694	1983	2692	2712	-
1970	1032	887	1984	1683	1879	-
1971	1088	800	1985	1111	1383	-
1972	1099	1278	1986	1083	1225	-
1973	1368	1150	1987	1235	1436	-
1974	1438	1220	1988	1215	1188	-
1975	1476	1734	1989	1336	1533	-
1976	2253	3187	1990	1857	1691	-
1977	4338	3477	1991	2060	-	2373
1978	4362	4730	1992	1946	-	3259

Theil's Inequality Coefficient for Ex-Post Forecast = 0.196

In this test, the model seems to adequately forecast, although with a slight overestimation, the 1991 CBT price. However, the 1992 forecast price is close to the previous test's result. In other words, it appears that in both cases the 1991 turning point is not well predicted by the model and the 1992 forecast price is equivalently

CBT Price Simulation and Forecast Results

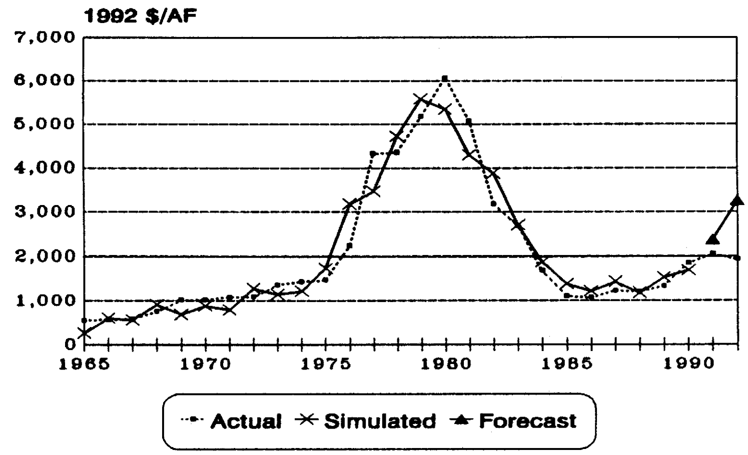


Figure 7-3

overestimated. Plus, the models' R^2 and the coefficient values and signs are overall consistent between both tests and the whole-period model. This suggests that collinearity may not affect the prediction ability of the model strongly, perhaps because existing collinear relationships hold consistently for the studied period. Some of these relationships can be expected to continue to hold, at least in the near future, such as the relationship involving economic growth (even upward trend) and agricultural CBT holdings (even downward trend), or the relationship involving CBT prices and inflation rate. Therefore, the influence of these near dependencies on the model predictions can be considered to be limited.

There are two potential reasons for explaining the lack of accuracy in predicting the 1991 price turndown, and therefore in forecasting the 1992 price. The first reason is that we were working with a very short data set. In other words, the information (or experience) carried by the data set was limited. Moreover, the CBT price series contained an exceptional feature, i.e., a very significant departure (1975-1985) from what appears to be its long-run trend. In fact, the model was developed with the objective of explaining such variation in price. People's expectations are highly variable over time, and they can be expected to be different today from what they were one or two decades ago. In other words, market participants can be expected to react differently to the same evolution in selected indicators at two different moments. Therefore, if we assume that global expectations concerning future water shortages and improved water use efficiency may have evolved since the 1970's, this could explain the fact that our model was not able to accurately predict the course of CBT prices outside the estimation period. What Figure 7-3 suggests is that the determinant-price relationships may have changed over time, which would make it difficult for any model to accurately forecast future water right prices.

The second potential reason for forecasting inaccuracy beyond one year is that an important variable may have been omitted in this model. It is possible that incorporating another variable would have helped to increase accuracy in predicting CBT prices outside the estimation period. However, we believe that the major potential water right price determinants were incorporated into the model.

In conclusion, it can be said that the proposed model and price determinants seem to accurately explain the behavior of CBT water right prices. The less accurate ex-post forecasts suggest that the relationships between these determinants and CBT unit prices may have changed. The existence of collinear relationships among certain variables does not seem to strongly affect the model's performance.

CHAPTER EIGHT: SUMMARY AND CONCLUSIONS

Water right markets are being proposed as a means to improve water use efficiency by transferring the property rights to water from lower valued to higher valued uses. In the few reasonably well defined water right markets that have developed in the maturing western water economy, the observed market prices have been highly variable. Knowledge about these prices is critical to understanding and evaluating water right transfers, however, very little theoretical or empirical knowledge has been developed regarding water right price determinants, relationships and trends. The purpose of this study is to identify potential water right price determinants and to analyze price-determinant relationships.

The economics of water right transfers is reviewed from a theoretical viewpoint. According to economic theory, price should be the measure of user's value or willingness-to-pay for a good. A review of the literature shows that wide ranges of value or willingness-to-pay estimates for water have been reported for different water uses, from typical annual values of $15 to $30 dollars per acre foot for water used in agriculture (the dominant water right owner and user in the western United States), to much higher values, up to several thousand dollars per acre foot, for domestic and industrial water uses. We hypothesize that water right prices are determined not only as a function of the value in production, but also as a function of other market factors and expectations.

The existing literature on similar studies being insignificant, a theoretical framework is developed to perform the study. The extensive body of economic literature on the rational expectations theory is reviewed and selected for application to water right markets. The rational expectations theory has been commonly applied to macroeconomic modeling and to financial and investment markets. In order to better understand the development and consequences of speculative pressures, suggested to exist or have existed in water right markets, the literature on speculative bubbles also is reviewed. To summarize, the speculative bubble literature provides a theoretical interpretation for speculation, and the rational expectations theory allows its incorporation in econometric models through market participants' expectations.

Potential water right price determinants are identified with the help of economic theory. Selected demand and supply shifters, speculation factors, market dominance and institutional factors are examined. A two-equation econometric model based on the rational expectations theory is developed to explain water right market price variation. This model incorporates historical information in the form of a linear distributed lag structure, which allows the number of degrees of freedom to be increased, and at the same time reduces potential ambiguity in the interpretation of the results. The model also incorporates future-valued expectations in order to account for potential speculative pressures.

The case study area selected for analysis is the Northern Colorado Water Conservancy District (NCWCD) service area, where one of the most well-established water markets known has developed since the early 1960's for the Colorado-Big Thompson (CBT) project imported water. Its legal characteristics make water highly transferable, in the form of homogeneous shares of the CBT project. The advantages of this area include its similarities with many other western regions (e.g. in the crops produced, the urbanization growth, etc.), and its legal characteristics which allow water right price variation to be isolated from the influence of institutional factors.

Water right price data were collected from several sources, and joined with other pertinent information such as the annual number of transfers, as well as the market structure (type of sellers and buyers for example). This additional information was collected from the minutes of the NCWCD Board of Directors monthly meetings. Published information about individual transactions and prices constituted a third source of information and showed the limited CBT price dispersion, thus justifying the use of average annual prices for the analysis.

The CBT water right prices are analyzed through descriptive and econometric analyses. The results suggest that the returns to water in irrigation do not adequately explain the CBT price level. Therefore, other factors are contributing to CBT water right price formation. The trend in population and the number of housing starts suggest that the sharp rise in CBT prices in the 1975-80 period was probably induced by a demand increase based on a real need for additional water. At the same time, other factors such as high inflation rates and low real interest rates seem to have played the role of accelerators. However, this increased need for water does not discard the possibility for a speculative bubble to have developed. For instance, farmers purchasing CBT units when the price was rising - and was largely above the irrigation value of water - were speculating on future capital gains to justify their investments. Similarly, developers and municipalities have probably accelerated their purchases during the same period to avoid paying a higher price in the future. All this suggests that expectations have played an important role in the determination of CBT market prices. Adapting Adelman's words (1975) to western water, we could propose:

> *The west's 'water crisis' or 'water shortage' was a fiction. But belief in the fiction was a fact.*

The downturn in CBT prices in 1980-81 can be explained by the conjunction of various factors including: the number of housing starts had been decreasing for a few years, real interest rates were very high, agricultural returns in corn production dropped, and precipitation increased sharply in 1980. In other words, observation of these factors in the late 1970's suggested that a continued price increase for CBT shares was unlikely. Since 1985, prices have stabilized and seem to exhibit a more random evolution than before, suggesting that speculative pressures have diminished or disappeared. This is also suggested by the forecast results of the model. Consequently, today's market participants seem more aware of potential benefits of increased water use efficiency than previously. This factor, combined with the longer market experience, makes it improbable for a price peak comparable to the one experienced around 1980 to happen again, at least in the near future.

Based on the CBT market, the econometric model developed for this analysis can successfully explain water right price variation. Its future expectations component allow a better modeling of the investment decision process regarding water rights. The ex-post forecast tests suggest that the model should not be the sole instrument used to forecast future prices. However, these tests were very insightful about probable changes in price-determinant relationships.

The present study should be of interest to water managers, policy makers or market analysts for three main reasons. First, it identifies a set of water right price determinants (including agricultural, socio-economic, financial and market factors) which can successfully explain the variation of water right prices. These factors should therefore be considered when analyzing the possible evolution of water right prices, or planning a new water development project. Second, the study stresses the importance of expectations (and their variability over time) in the market price formation. In other words, price-determinant relationships are based on market participants' perceptions of the future, and this element should also be taken into account when considering water right prices. Third, water rights seem to be considered as investment assets in practice, and some relevant "market signs" may be captured in markets for other investment commodities such as farmland, crude oil or precious metals.

This study needs to be expanded to other water right markets. Application of the same model to a market where prices have followed a different trend or where the economic situation is different would be most instructive. Moreover, in the future, price and market activity information will be available for longer periods, which will benefit future analyses in that it will allow consideration of more variables and/or gain in precision. Finally, further research would be desirable in estimating the specific real returns to water used for municipal development purposes.

APPENDICES

Appendix 1: Example of Transfer Approvals Reported in the Minutes of the NCWCD Board of Directors Monthly Meetings

APPLICATION FOR CHANGE
OF WATER ALLOTMENT CONTRACTS
December 17, 1993

From	S.T.R.	Acre-Foot Units	To	S.T.R.	Acre-Foot Units
Duvall/Carl	18 2 69	24	Carl, Robert	12 2 70	24
Dyer/Dyer	36 8 66	100	Dyer, Eddie	36 8 66	100
Loveland Ready-Mix Concrete Inc./ City of Loveland	15 & 16 5 69	100	Loveland Ready-Mix Concrete, Inc.	15 & 16 5 69	100
Turner/Parsons	30 & 31 6 66 & 25 & 36 6 67	10	Turner, Daniel	30 6 66 & 25 6 67	10
Litzenberger/St. Vrain & Left Hand Water Cons. Dist.	8 & 9 3 68	47	St. Vrain & Left Hand Water Cons. Dist.	Corp.	47
Weitzel/Lower Latham Res. Co.	26 7 68	40	Lower Latham Res. Co.	Corp.	40
Paragon Point Partners/Ft. Col-Lov Water Dist.	18 6 68	100	Paragon Point Partners Ft. Col-Lov Water Dist.	18 6 68 Corp.	50 50
25-66, Ltd./Ft. Col-Lov Water Dist.	27 3 68	70	25-66, Ltd. Ft. Col-Lov Water Dist.	27 3 68 Corp.	20 50
Amen/Ft. Col-Lov Water Dist.	13 3 58	76	Amen, Harry Ft. Col-Lov Water Dist	13 3 58 Corp.	16 60
Wild Wood Farm/ City of Longmont	5 6 68	100	Wild Wood Farm City of Longmont	5 6 68 TU	51 49
Dusbabek/Town of Lyons	6 6 68	16	Town of Lyons	TU	16
Lonetree Lake II/ Town of LaSalle	10 4 69	50	Town of LaSalle	TU	50

Appendix 2: CBT Unit Transfers by Seller Category

Year	Individuals, Farms, etc.	Irrigation Companies	Municipalities, Water Districts	Industry	Other	*Total*
1970	4694		125	52	10	4881
1971	7148			50	407	7605
1972	4365			80	838	5283
1973	3259			200	556	4015
1974	2372			445	252	3069
1975	2282	35			395	2712
1976	2430		284		314	3028
1977	3724	245	181		521	4671
1978	4652	100	307		875	5934
1979	5638	45	659	150	655	7147
1980	3792		829	1	570	5192
1981	2887		46	14	444	3391
1982	2765		280	46	222	3313
1983	1917			387	260	2564
1984	2895	31	52	250	438	3666
1985	3829	23	77	55	248	4232
1986	2521				233	2754
1987	4583		10		113	4706
1988	3040			5	200	3245
1989	3815		1465	51	293	5624
1990	3178	1	1550	20	103	4852
1991	4302		12	103	441	4858
1992	3611	10	25	15	330	3991
1993	3698			271	193	4162
Total	87397	490	5902	2195	8911	104895

Appendix 3: CBT Unit Transfers by Buyer Category

Year	Indiv., Farms...	Banks	Other Land Owners	Total Land Owners	Munici-palities	Industry	*Total*
1970	1508		15	1523	1317	2041	4881
1971	844	85	268	1197	2670	3738	7605
1972	1564	14	283	1861	2375	1047	5283
1973	1233		238	1471	2239	305	4015
1974	801			801	2003	265	3069
1975	793		37	830	1605	277	2712
1976	1173	20	78	1271	922	835	3028
1977	1790	11	56	1857	2587	227	4671
1978	1608		388	1996	3938		5934
1979	1910	5	681	2596	3511	1040	7147
1980	950		53	1003	4170	19	5192
1981	1191		111	1302	997	1092	3391
1982	611		722	1333	799	1181	3313
1983	1314		25	1339	728	497	2564
1984	1077			1077	1578	1011	3666
1985	654		454	1108	1865	1259	4232
1986	1195	20	63	1278	1396	80	2754
1987	1060		14	1074	3512	120	4706
1988	1261	50	553	1864	1271	110	3245
1989	1019	375	366	1760	3734	130	5624
1990	1226		33	1259	3548	45	4852
1991	1230		9	1239	3549	70	4858
1992	1222	137	31	1390	2510	91	3991
1993	1854		47	1901	2251	10	4162
Total	29088	717	4525	34330	55075	15490	104895

REFERENCES

Adelman, Morris A. (1975): "Is the Oil Shortage Real? Oil Companies as OPEC Tax-Collectors," in Edwin Mansfield, Ed.: *Micro-Economics Selected Readings*, W. W. Norton & Company, Inc., New York, NY.

Almon, S. (1965): "The Distributed Lag Between Capital Appropriations and Expenditures," *Econometrica*, 33, 178-196.

Anderson, Jay C. and John E. Keith (1977): "Energy and the Colorado River," *Natural Resources Journal*, 17, 157-168.

Anderson, Terry L. and James A. Turner (1993): "Marketing the West's Life Blood," *Water Resources Update*, 92, 22-26.

Associated Press (April 10, 1994): "Thomas: Federal Restrictions on Water Being Attacked," *The Daily Laramie Boomerang*, Laramie, WY.

Begg, D.K.H. (1982): *The Rational Expectations Revolution in Macroeconomics*, Philip Allan, Deddington, Oxford, UK.

Belsley, David A. (1991): *Conditioning Diagnostics - Collinearity an Weak Data in Regression*, John Wiley & Sons, New York, NY.

Billings, R. B. and D. E. Agthe (1987): "Equity, Price Elasticity, and Household Income Under Increasing Block-Rates for Water," *American Journal of Economics and Sociology*, 43 (3), 273-286.

Billings, R. B. and D.E. Agthe (1980): "Price Elasticities for Water: A Case of Increasing Block-Rates," *Land Economics*, 56, 73-84.

Blake, David (1991): "The Estimation of Rational Expectations Models: A Survey," *Journal of Economic Studies*, 18 (3), 31-70.

Blanchard, Olivier J. and Mark W. Watson (1982): "Bubbles, Rational Expectations, and Financial Markets," in P. Wachtel (Ed.), *Crises in the Economic and Financial Structure*. Lexington Books, Lexington, MA.

Bode, Dennis (August and September 1993), City of Fort Collins Water and Wastewater Utility, personal communications.

Buchholz, Todd G. (1990): *New Ideas From Dead Economists: An Introduction to Modern Economic Thought*. Plume Books, New York, NY.

Burmeister, Edwin and Kent D. Wall (1982): "Kalman Filtering Estimation of Unobserved Rational Expectations with an Application to the German Hyperinflation," *Journal of Econometrics*, 20, 255-284.

Bush, David B. and W. Martin (1986): *Potential Costs and Benefits to Arizona Agriculture of the Central Arizona Project*, University of Arizona College of Agriculture Technical Bulletin No. 254, Tucson, AZ.

Camerer, Colin (1989): "Bubbles and Fads in Asset Prices," *Journal of Economic Surveys*, 3 (1), 3-41.

Camerer, Colin F. (1987): "Do Biases in Probability Judgement Matter in Markets? Experimental Evidence," *American Economic Review*, 77, 981-997.

Chow, Gregory (1983): *Econometrics*, McGraw-Hill, Singapore.

Colby, Bonnie G., Kristine Crandall and David B. Bush (1993): "Water Right Transactions: Market Values and Price Dispersion," *Water Resources Research*, 29 (6), 1565-1572.

Colby, Bonnie G. (1989): "Estimating the Value of Water in Alternative Uses," *Natural Resources Journal*, 29, 511-527.

Council of Economic Advisers (1993): *Economic Report to the President 1992*, U.S. Government Printing Office, Washington, DC.

Cumby, R. E., J. Huizinga and M. Obsfeld (1983): "Two-Step Two-Stage Least Squares Estimation in Models with Rational Expectations," *Journal of Economic Dynamics and Control*, 9, 63-75.

Daubert, John T. and Robert A. Young (1981): "Recreational Demands for Maintaining Instream Flows," *American Journal of Agricultural Economics*, 63, 667-676.

Dhrymes, Phoebus J. (1981): *Distributed Lags - Problems of Estimation and Formulation*, North-Holland Publishing Company, Amsterdam, Netherlands.

Diba, Behzad T. and Herschel I. Grossman (1988): "The Theory of Rational Bubbles in Stock Prices," *Economic Journal*, 98, 746-754.

Evans, George E. (1986): "A Test for Speculative Bubbles in the Sterling-Dollar Exchange Rate: 1981-84," *American Economic Review*, 76, 621-636.

Fama, E. F. (1970): "Efficient Capital Markets: A Review of Theory and Empirical Work," *Journal of Finance*, 25, 383-417.

Flood, Robert P. and Peter M. Garber (1980): "Market Fundamentals Versus Price-Level Bubbles: The First Tests," *Journal of Political Economy*, 88, 745-770.

Foster, Henry S., Jr. and Bruce R. Beattie (1979): "Urban Residential Demand for Water in the United States," *Land Economics*, 55 (1), 43-58.

Gardner, Richard L. and Thomas A. Miller (1983): "Price Behavior in the Water Market of Northeastern Colorado," *Water Resources Bulletin*, 19 (4), 557-562.

Gibbons, Diana C. (1986): *The Economic Value of Water*, Resources for the Future, Ed., Washington, DC.

Gilles, Christian and Stephen F. Leroy (1992): "Bubbles and Charges," *International Economic Review*, 33 (2), 323-339.

Gisser, Micha (1981): *Intermediate Price Theory: Analysis, Issues, and Applications*, MacGraw-Hill Inc., New York, NY.

Gisser, Micha, Robert R. Lansford, William D. German, Bobby T. Creel and Mark Evans (1979): "Water Trade-off Between Electric and Agriculture in the Four Corners Area," *Water Resources Research*, 15 (3), 529-538.

Gottlieb, Bob and Peter Wiley (1987): "Selling Water, or Selling Out?", in High Country News (Ed.): *Western Water Made Simple*, Island Press, Washington, DC.

Gottlieb, Manuel (1963): "Urban Domestic Demand for Water: A Kansas Case Study," *Land Economics*, 39 (2), 204-210.

Grima, Angelo P. (1972): *Residential Water Demand: Alternative Choices for Management*, University of Ontario Press, Toronto, Ontario.

Guesnerie, Roger (1992): "An Exploration of the Eductive Justifications of the Rational-Expectations Hypothesis," *American Economic Review*, 82 (5), 1254-1278.

Hamilton, James D. and Charles H. Whiteman (1985): "The Observable Implications of Self-Fulfilling Expectations," Journal of Monetary Economics, 16, 353-373.

Hansen, L. P. and K. J. Singleton (1982): "Generalised Instrumental Variables Estimation of Non-Linear Rational Expectations Models," *Econometrica*, 50, 1269-1286.

Hartman, Loyal M. and Don Seastone (1970): *Water Transfers: Economic Efficiency and Alternative Institutions*, Resources for the Future, Johns Hopkins Press, Baltimore, MD.

Hirshleifer, Jack (1984): *Price Theory and Applications*, Third Edition, Prentice-Hall Inc., Englewood Cliffs, NJ.

Howe, Charles W. (1993): "Water Pricing: An Overview," *Water Resources Update*, 92, 3-6.

Howe, Charles W., J. K. Lazo and K. R. Weber (1990): "The Economic Impacts of Agriculture-to-Urban Transfers on the Area of Origin: A Case Study of the Arkansas River Valley in Colorado," *American Journal of Agricultural Economics*, 72 (5), 2300-2304.

Howe, Charles W., Dennis R. Schurmeier and W. Douglas Shaw, Jr. (1986): "Innovative Approaches to Water Allocation: The Potential for Water Markets.' *Water Resources Research*, April 1986, 22(4), 439-445.

Howe, Charles W. and F. P. Linaweaver (1967): "The Impact of Price on Residential Water Demand and Its Relation to System Design and Price Structure," Water Resources Research, 3 (1), 13-32.

Jacobs, James J., Gordon Fassett and Donald J. Brosz (1990): *Wyoming Water Law: A Summary*, B-849R, Cooperative Extension Service, College of Agriculture, and Wyoming Water Research Center, University of Wyoming, Laramie, WY.

Kelso, Maurice M., William E. Martin and Lawrence E. Mack (1973): *Water Supplies and Economic Growth in an Arid Environment*, University of Arizona Press, Tucson, AZ.

Khoshakhlagh, Rahman, F. Lee Brown and Charles DuMars (1977): *Forecasting Future Market Values of Water Rights in New Mexico*, Technical Completion Report No. 92, Water Resources Research Institute Project No. 3109-209, NM.

Kollar, K. L., Robert Brewer and Patrick H. MacAuley (1976): "An Analysis of Price/Cost Sensitivity of Water Use in Selected Manufacturing Industries," Bureau of Domestic Commerce Staff Study, Water Resources Council.

Lo, Andrew W. and A. Craig MacKinlay (1988): "Stock Market Prices Do Not Follow Random Walks: Evidence from a Simple Specification Test," *Review of Financial Studies*, 1, 41-46.

Martin, William E. and Gary B. Snyder (1979): "Valuation of Water and Forage from the Salt-Verde Basin of Arizona," Report to the U.S. Forest Service.

McCallum, B. T. (1976): "Rational Expectations and the Natural Rate Hypothesis: Some Consistent Estimates," *Econometrica*, 44 91), 43-52.

McDonnell, Lawrence J. (1990): *The Water Transfer Process as a Management Option For Meeting Changing Water Demands*, Award No. 14-08-0001-G1538, U.S. Geological Survey, Reston, VA.

Meese, Richard A. (1986): "Testing for Bubbles in Exchange Markets: A Case of Sparkling Rates?" *Journal of Political Economy*, 94, 345-373.

Michelsen, Ari M. (1988): *Economics of Optioning Agricultural Water Rights for Urban Water Supplies During Drought*, Ph.D. Dissertation, Department of Agricultural and Resource Economics, Colorado State University, Fort Collins, CO.

Michelsen, Ari M. and Robert A. Young (1993): "Optioning Agricultural Water Rights for Urban Water Supplies During Drought," *American Journal of Agricultural Economics*, 75, 1010-1020.

Michelsen, Ari M. and Robert A. Young (1992): "Water Right Price Trends and Influences: A Rocky Mountain Region Case Study," Proceedings of the Fifth meeting of the American Water Resources Association, Wyoming State Section, Laramie, WY, October 28-30.

Mills, E. S. (1962): *Price, Output and Inventory Policy*, Wiley, New York, NY.

Muth, John F. (1961): "Rational Expectations and the Theory of Price Movement," *Econometrica*, 29, 315-335.

National Research Council (1992): *Water Transfers in the West*, National Academy Press, Washington, DC.

Neter, John, William Wasserman and Michael H. Kutner (1989): *Applied Linear Regression Models*, Irwin, Homewood, IL.

Nieswiadomy, Michael L. (1992): "Estimating Urban Residential Water Demand: Effects of Price Structure, Conservation, and Education," *Water Resources Journal*, 28 (3), 609-615.

Pindyck, Robert S. and Daniel L. Rubinfeld (1991): *Econometric Models and Economic Forecasts*, Third Edition, McGraw-Hill, Inc., New York, NY.

Plotkin, Steven E., Harris Gold and Irvin L. White (1979): "Water and Energy in the Western Coal Lands," *Water Resources Bulletin*, 17 (1), 94-107.

Pokorny, Michael (1987): *An Introduction to Econometrics*, Basil Blackwell Ltd., Oxford, UK.

Radosevich, George (1976): *Evolution and Administration of Colorado Water Law: 1876-1976*, Fort Collins: Water Resources Publications.

Randall, Alan (1987): *Resource Economics: An Economic Approach to Natural Resource and Environmental Policy*, Second Edition, John Wiley & Son, New York, NY.

Randall, Alan (1981): "Property Entitlements and Pricing Policies for a Maturing Water Economy," *Australian Journal of Agricultural Economics*, 25 (3), 195-212.

Russel, Clifford S. (1970): "Industrial Water Use," Report to the National Water Commission.

Saliba, Bonnie Colby and David B. Bush (1987): *Water Markets in Theory and Practice: Market Transfers, Water Values and Public Policy*, Studies in Water Policy and Management No. 12, Westview Press, Boulder, CO.

Scharfstein, David S. and Jeremy C. Stein (1990): "Herd Behavior and Investment," *American Economic Review*, 80 (3), 465-479.

Shaw, Graham K. (1984): *Rational Expectations: An Elementary Exposition*. St. Martin's Press, Inc. New York, NY.

Sheffrin, Steven M. (1983): *Rational Expectations*, Cambridge University Press, Cambridge, UK.

Shiller, Robert J. (1978): "Rational Expectations and the Dynamic Structure of Macroeconomic Models: A Critical Review," *Journal of Monetary Economics*, 4, 1-44.

Shiller, Robert J. (1981): "Do Stock Prices Move Too Much To Be Justified by Subsequent Changes in Dividends?" *American Economic Review*, 71, 421-436.

Shumway, C. R. (1973): "Derived Demand for Irrigation Water: The California Aqueduct," *Southern Journal of Agricultural Economics*, 5 (2), 195-200.

Shupe Steven J., Gary D. Weatherford, and Elizabeth Checchio (1989): "Western Water Rights: The Era of Reallocation," *Natural Resources Journal*, 29, 413-434.

Smith, Vernon L., Gerry L. Suchanek and Arlington W. Williams (1988): "Bubbles, Crashes, and Endogenous Expectations in Experiment Spot Asset Markets," *Econometrica*, 56 (5), 1119-1151.

Stevens, Thomas H. and Robert J. Kalter (1975): "Forecasting Industrial Water Utilization in the Petroleum Refining Sector: An Overview," *Water Resources Bulletin*, 11 (1), 156.

Stratecon, Inc.: *Water Strategist*, Selected Issues, Claremont, CA.

Stratecon, Inc.: *Water Intelligence Monthly*, Water Strategist Supplement, Claremont, CA.

Taylor, David T. (1987): *Agricultural Land Prices in Localized Rural Land Markets: The Dual Role of Land As a Good-Resource*, Ph.D. Dissertation, Department of Agricultural and Natural Resource Economics, Colorado State University, Fort Collins, CO.

Tegene, Abebayehu and Fred Kuchler (1990): *The Contribution of Speculative Bubbles to Farmland Prices*. Resources and Technology Division, Economic Research Service, U.S. Department of Agriculture. Technical Bulletin No. 1782.

Thomas, John F. and Geoffrey J. Syme (1988): "Estimating Residential Price Elasticity of Demand for Water: A Contingent Valuation Approach," *Water Resources Research*, 24 (11), 1847-1857.

Tirole, Jean (1985): "Asset Bubbles and Overlapping Generations," *Econometrica*, 53, 1071-1100.

Tirole, Jean (1982): "On the Possibility of Speculation Under Rational Expectations," *Econometrica*, 50 (5), 1163-1181.

U.S. Department of Agriculture: *Agricultural Statistics*, 1960-1992, U.S. Government Printing Office, Washington, DC.

U.S. Department of Agriculture, Economic Research Service: *Economic Indicators of the Farm Sector, Costs of Production - Major Field Crops, 1990*, Washington, DC.

U.S. Department of Agriculture, Economic Research Service: *Economic Indicators of the Farm Sector, State Financial Summary*, Selected Issues, Washington, DC.

U.S. Department of Agriculture, Economic Research Service: *Farm Sector Balance Sheet, Including Operator Households, 1960-89*, Washington, DC.

U.S. Department of Agriculture, Economic Research Service: *Situation and Outlook Summary (Agricultural Resources: Agricultural Land Values)*, Washington, DC.

U.S. Department of Commerce, Bureau of Economic Analysis: *State Personal Income, 1929-87: Estimates and a Statement of Sources and Methods*, Washington, DC.

U.S. Department of Commerce, Bureau of Economic Analysis: *Survey of Current Business*, July Annual Summary, 1960-1993, Washington, DC.

U.S. Department of Commerce, Bureau of Economic Analysis, Regional Economic Information System (1969-1991), Table CA05, Washington, DC.

U.S. Department of Commerce, Bureau of the Census: *County and City Data Book 1960*, Washington, DC.

U.S. Department of Commerce, Economics and Statistics Division: *Housing Units Authorized by Building Permits: Annual 1960-1992*, Current Construction Reports, C40-9013, Washington, DC.

U.S. Department of Energy, Energy Information Administration: *Annual Energy Review*, 1960-1993, Washington, DC.

U.S. Water Resources Council (1978): *The Nation's Water Resources 1975-2000*, vol. 1, U.S. Government Printing Office, Washington, DC.

Wahl, Richard W. and Frank H. Osterhoudt (1986): "Voluntary Transfers of Water in the West," *National Water Summary 1985*, U.S. Department of Interior, Washington, DC.

Wallis, Kenneth F. (1972): *Introductory econometrics*, Aldine Publishing Company, Chicago, IL.

Wallis, Kenneth F. (1988): "Some Recent Developments in Macroeconometric Modelling in the United Kingdom," *Australian Economic Papers*, 27, Supplement, 7-25.

Walsh, Richard G., Ray K. Ericson, Daniel J. Arosteguy and Michael P. Hansen (1980a): "An Empirical Application of a Model for Estimating the Recreation Value of Instream Flow," Colorado Water Resources Research Institute Completion Report No 101, Colorado State University, Fort Collins, CO.

Walsh, Richard G., Robert Auckerman and Robert Milton (1980b): "Measuring Benefits and the Economic Value of Water in Recreation on High Country Reservoirs," Colorado Water Resources Research Institute Completion Report No 102, Colorado State University, Fort Collins, CO.

West, Kenneth D. (1987): "A Specification Test for Speculative Bubbles," *Quarterly Journal of Economics*, 102, 553-580.

Western Network (1987-89): *Water Market Update*, Santa Fe, NM.

Whiteman, C. H. (1983): *Linear Rational Expectations Models*, University of Minnesota Press, MN.

Wickens, M. R. (1982): "The Efficient Estimation of Econometric Models with Rational Expectations," *Review of Economic Studies*, 69, 55-67.

Willes, Mark H. (1980): "'Rational Expectations' as a Counterrevolution," *The Public Interest*, Special Summer Issue.

Wong, S. T. (1972): "A Model on Municipal Water Demand: A Case Study of Northeastern Illinois," *Land Economics*, 48 (1), 34-44.

Young, Robert A. (1984): "Direct and Indirect Regional Economic Impacts of Competition for Irrigation Water", in Ernest A. Englebert, Ed., *Water Scarcity: Impacts on Western Agriculture*, University of California Press, Berkeley, CA.

Young, Robert A. and S. Gray (1972): *Economic Value of Water: Concepts and Empirical Estimates*, U.S. National Water Commission Technical Report No. PB210356.