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Water Rights Heterogeneity and Price Determination: How Market and Product Attributes Affect Agricultural Water Market Prices

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Abstract

This research aims to further the understanding of price behavior in predominantly agricultural water markets through a hedonic estimation of the impact of market and product attributes on water rights prices in the Cachapoal River Valley of South-Central Chile. It is hypothesized that the price of a water right in the valley is primarily a function of the reliability of that water right (product attribute) and the increasing relative scarcity of water in the valley (market attribute). This article aims to test the joint hypotheses that reliability and relatively scarcity positively affect water rights prices. In addition, it will estimate the magnitude of these product and market attributes on market prices.

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Introduction

Since the early 1980s, there has been a surging interest in the use of private markets in the allocation of scarce water resources. Early work focused on debating the advantages and disadvantages of moving to markets in tradable water rights (Rosegrant and Binswanger 1994; Griffin and Hsu 1993; Colby Saliba and Bush 1987; Howe and Shaw, 1990, Anderson 1983) and simulations of potential water market outcomes (Weinberg et. al 1993; Dinar and Lety 1991, Howe et. al. 1990; Vaux and Howitt 1984.

In theory, a water market allows the most efficient allocation of resources as those users who value water most highly bid away resources from lower-valued uses. In equilibrium, the value of the marginal product of water is equalized within trading areas and there exists a single market price. This presumes, however, that water rights are homogeneous goods. Those who view water rights in this light claim that price dispersion is a sign of thin markets. Other authors point out, however, that price dispersion is rather a reflection of the heterogeneity of water rights as commodities and the particular characteristics of each market (Colby et al, 1993, Bjornlund and McKay, 1998). Since water rights are not homogeneous goods, their attributes, as well as the unique characteristics of the market in which they are transacted, will affect the prices paid for them.

This research aims to further the understanding of price behavior in predominantly agricultural water markets through a hedonic estimation of the impact of market and product attributes on water rights prices in the Cachapoal River Valley of South-Central Chile. It is hypothesized that the price of a water right in the valley is primarily a function of the reliability of that water right (product attribute) and the increasing relative scarcity of water in the valley (market attribute). This article aims to test the joint hypotheses that reliability and relatively scarcity positively affect water rights prices. In addition, it will estimate the magnitude of these product and market attributes on market prices.

Literature Review

There have been few studies of price behavior in water markets. Where established water markets do exist, it is often difficult to obtain reliable price and transactions information. Gardner and Miller (1983) provide the first analysis of water market prices in the Colorado Big Thompson water market. They find that between 1961 and 1972, real water rights prices increased thirty-fold, an increase that far outpaced agricultural returns during the same period. They attribute this increase to the speculation value of irrigation water rights in more highly valued alternative municipal and industrial uses. Dourojeanni and Jouravlev (1999), examining the water market in Chile, indicate that water rights prices show sustained increases over time. They attribute this phenomena to the increasing relative scarcity of water, but they provide no empirical analysis to substantiate their claims. Colby et. al (1987) focus on potential differences between market prices and the marginal social value of water. They submit that most water markets deviate from the competitive model, suggesting that prices are but a rough approximation of the social value of additional water supplies.

None of the above studies relates the characteristics of different water rights to their prices. The hedonic estimation technique is particularly useful for such a study. Hedonic studies have been used to analyze the effects that different characteristics of a good have on its price. Once marginal characteristics prices have been estimated, they can then be used to analyze the underlying demands for the different characteristics of a good. Hedonic methods are based on the realization that some goods or factors of production are not homogeneous goods and can differ in numerous characteristics. A water right is a clear example of a heterogeneous good. They differ in quality, quantity and variability and their productivity is often linked to their location. Crouter (1987) was the first to apply hedonic estimation to water markets in which water and land are transacted together to the implicit price of water in the transaction. Colby et. al (1993) and Bjornlund and McKay (1998) followed with hedonic estimation of water rights prices in markets where water was sold separately from land. Both studies found that water values have increased over time and that certain buyers in the market pay a premium for water rights prices. They also demonstrated that there exists a discount in the unit price for large purchases of water (or correspondingly a premium for small purchases). The similarity of these studies´ conclusions is striking given that they were each carried out in very different river basins in different time periods Colby et. al examine water rights transactions in the Gila San Francisco basin of New Mexico from 1971 to 1987 whereas Bjornlund and McKay study a rural water market in South Australia during the period 1987-1993. Further hedonic studies of water markets, therefore, may enable researchers to identify trends and characteristics common to all markets. This article aims to contribute in this vein by providing a hedonic estimation of water rights prices in the Cachapoal River Valley of Chile from 1990-1999.

The remainder of this article is organized as follows. First background information on Chilean water legislation since the inception of the water market is present along with a description of the Cachapoal river valley. This is followed by an exposition of the conceptual framework used in the analysis, a description of the data and summary statistics and formal presentation of the hedonic price model. Concluding remarks follow and analysis and discussion of the results.

Background on Chilean Water Legislation

The first free-standing water legislation in Chile was promulgated with the 1951 Water Code, which granted private property status to usufructory rights over water resources while maintaining the state ownership of the physical water resources.. Water rights were granted as concessions in which the grantee was required to specify the use to which the water would be put as well as demonstrate that there existed adequate distribution infrastructure to capture and deliver the water right. In addition, water rights that were not exercise for a period of five years could be expropriated by the State. Since use rights were private property, they could be traded, rented or mortgaged. This was the beginning of the water market in Chile.

In 1967, the agricultural sector in Chile underwent a radical transformation as the State expropriated large estates, which they later divided into smaller parcels and redistributed to a new class of small landowners created by the Agrarian Reform. Together with land, water use rights were also expropriated and state control of these rights was strengthened. Water rights lost their designation as private property and could no longer be traded. This water market moratorium lasted until 1981 with the appearance of the current Water Code.

The 1981 Water Code is in many ways a return to the 1951 Code. Private property rights have been re-established and trading is allowed. In addition, the beneficial use clause, which gave the State the power to expropriate water rights that had not been used for a period of five years, has been eliminated. Users are no longer required to specify the use to which they intended to put the water rights solicited from the State, nor are they obligated to demonstrate that they possess infrastructure capable of capturing and delivering such water rights. As a result, the 1981 Water Code opened up a window of opportunity for speculation in water rights that did not previously exist.. This possibility of speculation has led many researchers to believe that water rights prices have been steadily increasing over time since 1981.

Description of Study Area

The Cachapoal River Valley is located in the sixth region of Chile, just south of the Santiago Metropolitan Area. The region is characterized by high value export crops and is home to several multinational agricultural export firms, due to its expedited access to the country's two major ports: San Antonio and Valparaíso. In land area, it is superseded only by Santiago, covering over one and a half million hectares. Agricultural activity accounts for 26 percent of the regional economy and is concentrated in the production of export fruit, livestock, vegetable crops and cereals. The region produces 45 percent of apple production, 25 percent of table grape production , 55 percent of corn production and 43 percent of livestock production at the national level (Pastures account for 56 percent of land use.).

The Cachapoal River valley covers 44 percent of the land area within the region (See Map). It has its source at the foot of the Pico del Borroso summit, 5,160 feet above sea level, and it cuts through the Cachapoal river valley, flowing 164 kilometers to the Pacific Ocean. The river basin extends over 7,155 square kilometers and is characterized by a Mediterranean climate where the greatest river flows are produced during the winter months and the snowmelt period between spring and summer. River flows peak in June-July and December.

The Cachapoal river covers the Cachapoal province almost in its entirety. Of a total of 17 communes within the province, only four receive water from other sources. The river is divided into three administrative sections of which the first is the largest, covering 73.4 percent of the river valley's land area. This section extends to Punto de Cortés, just above the confluence of the Estero La Cadena with the Cachapoal river, where the second section of the river begins. This section is much smaller in importance, covering less than 10 percent of the land area of the river valley and extending to the confluence of the Estero Purén with the Cachapoal River. This section differs significantly from the other two in that it is supplied principally by return flows and infiltrations from the first section. As a result, there is very little water market activity in this zone. The final section of the river extends to the end of the Cachapoal River at its confluence with the Tinguirririca River. Tables 1 and 2 provide information on irrigation technology and land use along the river by section.

Figure 1: Map of Cachapoal River Valley, Sixth Region, Chile

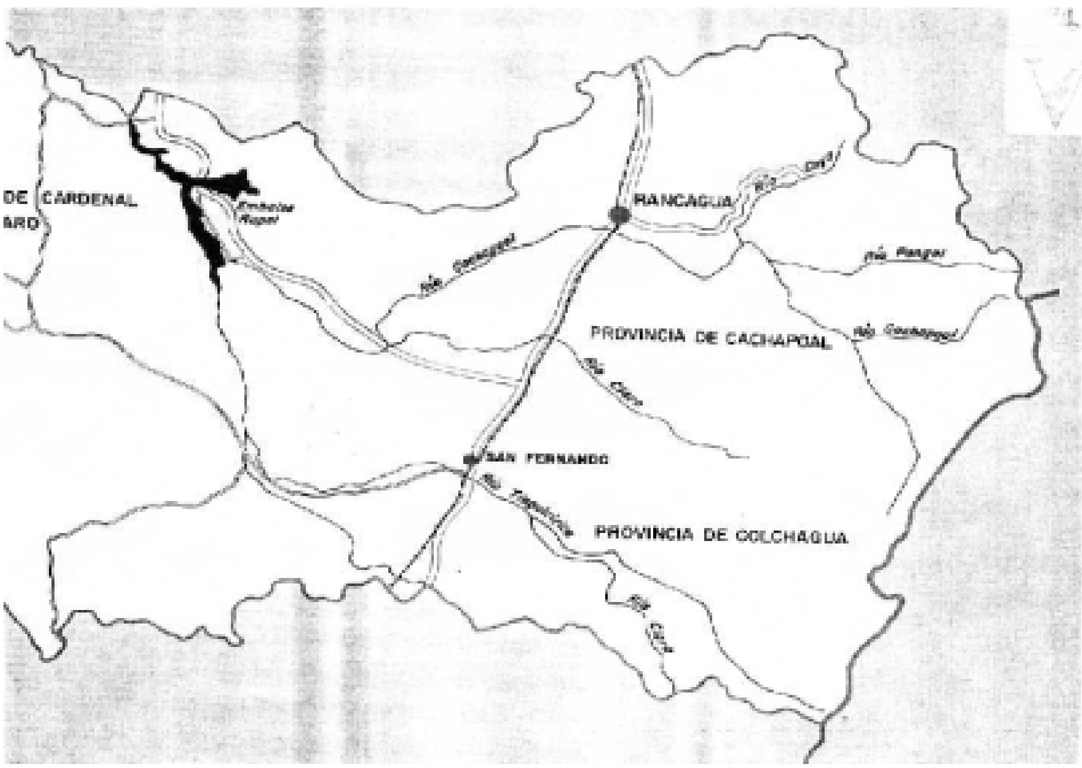

Table No. 1: : Infrastructure and Number of Irrigators by Section: Cachapoal River

	Section 1	*Section 2*	*Section 3*	*River*
Diversion Points	12	13	8	33
Canals	31	19	11	61
Irrigators	10.272	4.147	4.888	19.307

Source: Agricultural Census Data, 1997

Table No.2: Land Use and Irrigation Systems in the Cachapoal River

	Land Use Percent of Arable Land Area		**Irrigated Systems Percent of Arable Land Area**		
	Ag and Livestock	*Forestry*	*Furrow*	*Sprinkler*	*Drip*
Section 1	63.1	36.7	93.4	2,1	4,5
Section 2	66.8	33.2	98.4	0,6	1,0
Section 3	90.1	9.9	91.4	1,7	6,9

Source: Agricultural Census Data, 1997

Methodology and Data

Conceptual Framework

A water right is a heterogeneous good as rights located in different sectors vary in productivity, variability and mean flows. We may refer to this characteristic of water rights as spatial heterogeneity, the amount that a water right differs based on its geographic location. Variability of water flows may manifest itself between seasons as the hydrological cycle moves from wetter to drier years, within seasons, depending on the timing and availability of flows during growing season. It may also, however, manifest itself based on the distribution infrastructure and location of the water right along the river. It is this type of spatial variability that is the focus of the present analysis. Those water rights located upstream, for example, will generally by the most reliable with the greatest mean flows. As one moves downstream, however, return flows and conduction losses begin to become more important. These factors will always, increase the variability of water flows to downstream users, either positively or negatively. As more users enter the system and begin to remove and return water flows, the flows to downstream farmers will become more variable. This phenomena will present itself both within and across growing seasons. Reductions in water supply over time are often positively correlated with conduction losses along a river, in many cases leaving those users at the end of the river without water, or with a water supply so unreliable, that agricultural production becomes impossible.

In addition to geographical factors, the infrastructure used to capture and deliver water to rights holders may influence the water flow variability. In the Cachapoal River Valley water is delivered by either permanent concrete structures or by rustic temporary structures. . Permanent structures are more reliable than temporary structures because temporary structure require constant supervision to ensure that water is distributed accurately and on time.

Temporary structures must also be periodically replaced, potentially disrupting or distorting flows to users over time. The type of structure used to deliver water rights is often a function of the organization and efficiency of water user associations as well, where larger more organized associations have installed permanent structures and the more fragmented groups of users rely on temporary structures. In this sense, irrigation district efficiency indirectly increases the reliability of water right flows.

Thus the variability of water flows may be positively affected by both their spatial heterogeneity and by the efficiency of the irrigation district to which they are assigned. To capture the effects of these factors, two sets of binary variables are included in the model. The first set of variables identify the location of the water right by section, where the first section is that located the farthest upstream and the third section is that located at the tail end of the river. The second section is used as the benchmark. The second binary variable identifies the type of infrastructure used to capture and deliver the water right, where a value of one is used to identify temporary structures. These structures are identified with inefficient irrigation districts.

Other factors which may affect the price of a water right may be related more to the market than to the actual product. There have been no studies done of water market structures, apart from a few studies on the thinness of water markets in general. However, it is completely possible to observe in water markets, behaviors typical of other markets such as price discrimination in the form of quantity discounts. To capture the possibility of quantity discounts, the quantity of water rights transferred per transaction is regressed against the unit price of the transaction. A negative sign for the coefficient of this variable would imply a volume discount whereas a positive sign would imply a premium or increasing unit price for large purchases. This latter phenomena may be completely plausible if we assume that farmers attach an increasing marginal value to their stock of water rights as that stock diminishes.

Finally, we may expect agents in the water market to have differing reservation prices for water rights. It is expected that well-known firms or farmers identified as important forces in the regional agricultural economy may value water rights more highly than smaller and less known buyers. Transactions costs for these farmers may also be lower as they may possess more market information and better skills in the area of negotiation, contracting and subsequent protection of the integrity of the water rights they purchase. Lower costs combined with higher reliability of water right delivery may imply that these actors would be willing to pay more per unit of water than other buyers. The existence of such buyers was first postulated by Colby et al (1993) which found that buyers such as city governments, public utilities or dominant actors in the regional economy tend to pay higher prices for water rights to avoid negative public perceptions of price gouging behavior.

Finally, it is generally believed that water rights prices are increasing over time. This is due to the increasing demand for water over time in the fact of fixed supplies of both water rights and water volumes, translating into an increasing relative scarcity of water over time. This increasing relative scarcity is expected to generate an increase in the value of water rights over time (Donoso, 1995).

Data

Data on permanent water rights transactions from 1990 to 1999 in the Cachapoal River Valley were collected from local Real Estate and Judicial Archives offices and compared with the original purchase agreements to verify sales prices and transaction dates. Only water rights sold without land are included in the analysis for a total of 126 transactions.

Tables 3 and 4 provide some descriptive statistics of the data for all canals and for the top four canals in terms of transactions.

Table 3: Descriptive Statistics, All Transactions

Variable	*No. Obs.*	*Mean*	*Max*	*Min*	*Mode*	*Std. Dev*
Quantity (partes del río)		0.459	7.583	0.002	1.0	0.848
Price (CH$)		82,275,780	604,198,877	68,472	352,072,689	156,659,902
Section1	101					
Section2	6					
Section3	19					
High Profile	28					
Perm Infr.	101					
TOTAL TRANS	126					

Table 4: Descriptive Statistics, Top Four Canals in terms of Transactions

Variable	*Lucano*	*Cocalán*	*Peterson*	*Punto de Cortés*	*percent of Total*
· #Trans	29	18	19	11	61
Quantity (Partes del Río)					
Mean	0.215	1.057	0.418	0173	
Std. Dev	0.475	1.917	0.419	0.229	
Max	2.469	7.583	1.712	0.83	
Min	0.006	0.032	0.077	0.003	
Unit Price (CH$)					
Mean	247,111,514	2,476,989	14,777,354	127,166,216	
Std. Dev	206,470,017	2,027,770	7,744,977	232,943,510	
Max	526,781,459	8,710,544	29,532,684	604,198,877	
Min	267,350	333,821	1,968,249	8,960,906	
High Profile	17	0	2	3	75
Perm. Infrast.	29	18	19	11	76
Section	1	3	1	1	

The 1981 Water Code in Chile requires that all water rights be defined in volumes per unit of time. In practice, however, water rights may be defined in such diverse units as liters per second, cubic meters, percentages of the river, rights in the river, regadores and acciones. In the Cachapoal River Valley, all transactions collected were expressed in acciones. These acciones, however, represent differing volumetric equivalents depending on the canal to which they are assigned. In order to compare price differences between canals, therefore, all acciones was transformed into partes del río o river rights. Each canal is assigned a certain quota of rights in the river. This quota is divided into acciones and distributed among the members of the canal based on an internal division factor, which varies by canal. Using this internal division factor, it is possible to retransform the acciones to river rights, which is standard measure for the entire valley. Using this measure, and the transformed prices, we may proceed with the hedonic analysis for the entirety of the river valley.

Functional Form and Econometric Model

Much has been written about the appropriate functional forms of hedonic price regressions. Rosen (1974) was the first to postulate the nonlinearity of such equations due to the inseparability of the product attributes. Empirically, however, the linear model is advantageous in its ease of computation and the transparency of the regression coefficients which represent the marginal willingness to pay for product attributes. Finally, the appropriate functional form becomes an empirical question. In this model, several functional forms were explored including the semi-log, double log, and Box-Cox transformations. Although a Box-Cox transformation of all the continuous variables yielded the best fit, a log linear model was chosen since it differed little in terms of fit compared with the Box-Cox and for the ease of interpretation of its coefficients as price flexibilities. The regression equation estimated therefore is:

$$\ln P_{it} = \beta_0 + \beta_1 \ln T_{it} + \beta_2 C_{it} + \beta_3 \ln Q_{it} + \beta_4 S_{1it} + \beta_5 I_{it} + \varepsilon_{it} \qquad \textbf{(1)}$$

where P is the price of a river right, T is a time trend, and Q is the quantity of river rights transferred in the transaction. The variable C identifies the high profile buyers and the variable S_1 is a locational variable which identifies those transactions realized in the first section of the river. Irrigation district efficiency and infrastructure reliability is represented by the variable *I*. .

Results and Discussion

Results from the econometric estimation are presented in Table 5 Of the five independent variables presented in the model, four are significant at the 1 percent level. The adjusted R^2 is 0.7515, demonstrating that the variables included in the analysis explain to a large extent water rights prices in the valley.

Table 5: Coefficient Estimates of Hedonic Price Model

Variable	*Estimated Coefficient*	*Exponential of Coefficient*	*Std. Error*	*T-Statistics*
Quantity	-0.4576	N/A	0.0833	-5.490
Time	0.0445	N/A	0.1728	0.258
Section 1	1.3634	3.91	0.2538	5.372
Profile	2.5516	12.83	0.3008	8.482
Tipocap	-1.3804	0.25	0.2455	-5.622
Constant	14.0990	N/A	0.3984	35.390

Water Rights Variability

As stated in the conceptual framework, one important indicator of flow variability is the location of the water right along the river, where water rights located furthest upstream will be less variable, and therefore command higher prices, than those located further downstream. ´The results of the regression support this hypothesis. Water rights in the first section command prices 291 percent higher than those located further downstream in the second and third sections.

The second variable included in the analysis to capture the effect of flow variability is the type of infrastructure used to capture and deliver the water right, which is highly correlated with the efficiency of the irrigation district that manages that right. The results indicate that water rights managed by more efficient irrigation districts command prices 75 percent higher than those managed by fragmented farmer groups.

Price discrimination in the form of quantity discounts exist in the water market. A ten percent increase in the quantity of river rights purchased results in a 4.6 percent discount in the unit price. This discount is small but highly significant in the model. It is helpful to note that a 10 percent increase in river rights is equivalent to between an increase of x to x number of water rights.

High profile buyers are shown to pay considerably more for water rights than their lesser known piers. A high profile buyer on average pays approximately 10 times more in the unit price than other farmers in the market. It should be pointed out, however, that these buyers tend to buy small quantities of water rights and therefore often do not take advantage of quantity discounts available in the market. These buyers may also have much higher marginal products of water.

Finally, there is no statistically significant relationship between the price of water rights and the time trend. This implies that the price of water rights are not increasing over time despite the increasing relative scarcity of water. This is a curious result but can be possibly explained by the existence of cheaper substitutes for water rights to increase on-farm water supply. These substitutes may include both improvements in irrigation efficiency, through the installation of drip or other types of mechanized irrigation systems, or use of groundwater supplies. Since the mid 1980s in Chile, the government has offered subsidies to farmers to install drip irrigation systems. Such systems may be able to more than double a farmer’s on farm water supply, negating the need to purchase additional rights. Groundwater pumping may also be more economical than purchasing water rights. Finally, both alternatives may also provide more reliable flows than the acquisition of additional water rights.

Conclusions

A water right that delivers a less variable flow is more highly valued in the market than one which delivers a more volatile flow. This result can be seen in the reduction in the prices paid for water rights as one moves downstream and in the fact that water rights delivered by more secure infrastructure command higher prices than those delivered by less secure infrastructure. We can also interpret this result as the value attributed to a water right according to its hydrological priority since those water rights located closer to the source of the river are the first to be fulfilled in the event of a drought. As such, it is quite possible that during droughts, those water rights located in the tail end of the river may never be fulfilled. The existence of a hydrological priority affects the price of a water right, where one must pay a premium for water rights that are found closer to the source of the river.

Water rights prices do not respond to the increasing relative scarcity of water, an unexpected result. If we accept that relative scarcity is increasing over time, we must conclude that there exist close substitutes to the purchase of new water rights in the zone. The demand for water rights is not increasing because water resources are being freed up through improvements in irrigation efficiency, generating a more efficient use of the resource.

Discounts in unit prices are offered for large purchases of water rights in the market. These discounts are on the order of 4,6% for a 10% increased in water rights purchased. Parallel to this result, certain buyers in the water market will pay a premium in the unit price for water rights which is ten-fold that paid in the average transaction. These buyers tend to important actors in the regional agricultural market and it is thought that they possess greater information and are able to extract higher marginal values in water use than other agents in the market.

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